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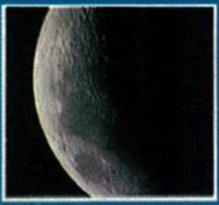

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Cover

Since the first orbital views of our planet were returned, it's been impossible to think of Earth as a limitless source of supply for man. It *is* limited: From space it doesn't even seem very big. This month ASTRONOMY explores two aspects of that simple but profound fact. The first is the possibility of recovering materials from the asteroids — which will become possible even within this century. Second is the monitoring of Earth from orbit — watching the day-to-day meteorological behavior of our planet — in part to understand what drives the great natural cycles of weather. This month the observing departments are devoted to the solar eclipse coming on Feb. 26, 1979; we know you won't want to miss it! Earth photograph from Apollo 17, courtesy of NASA.

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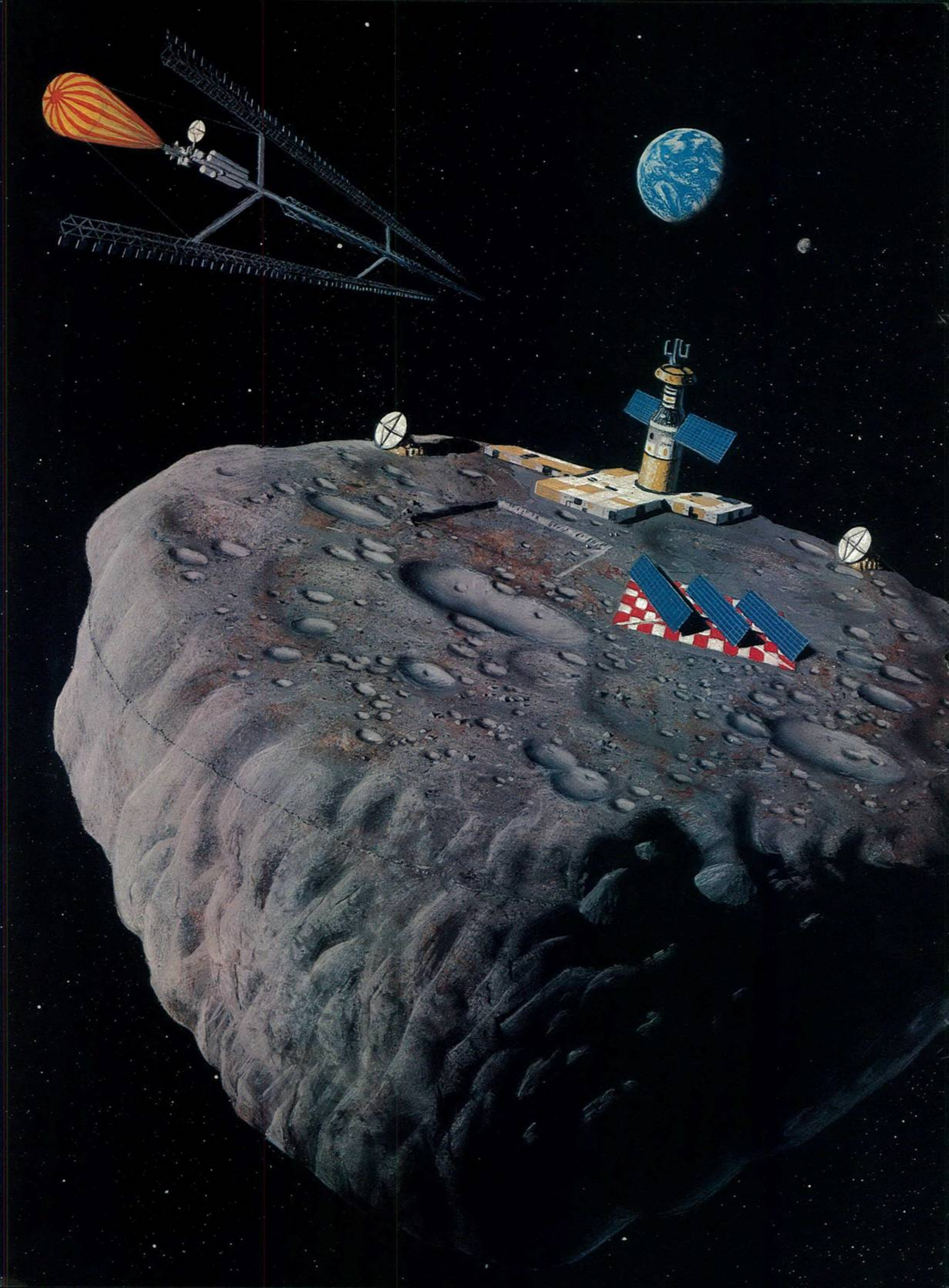
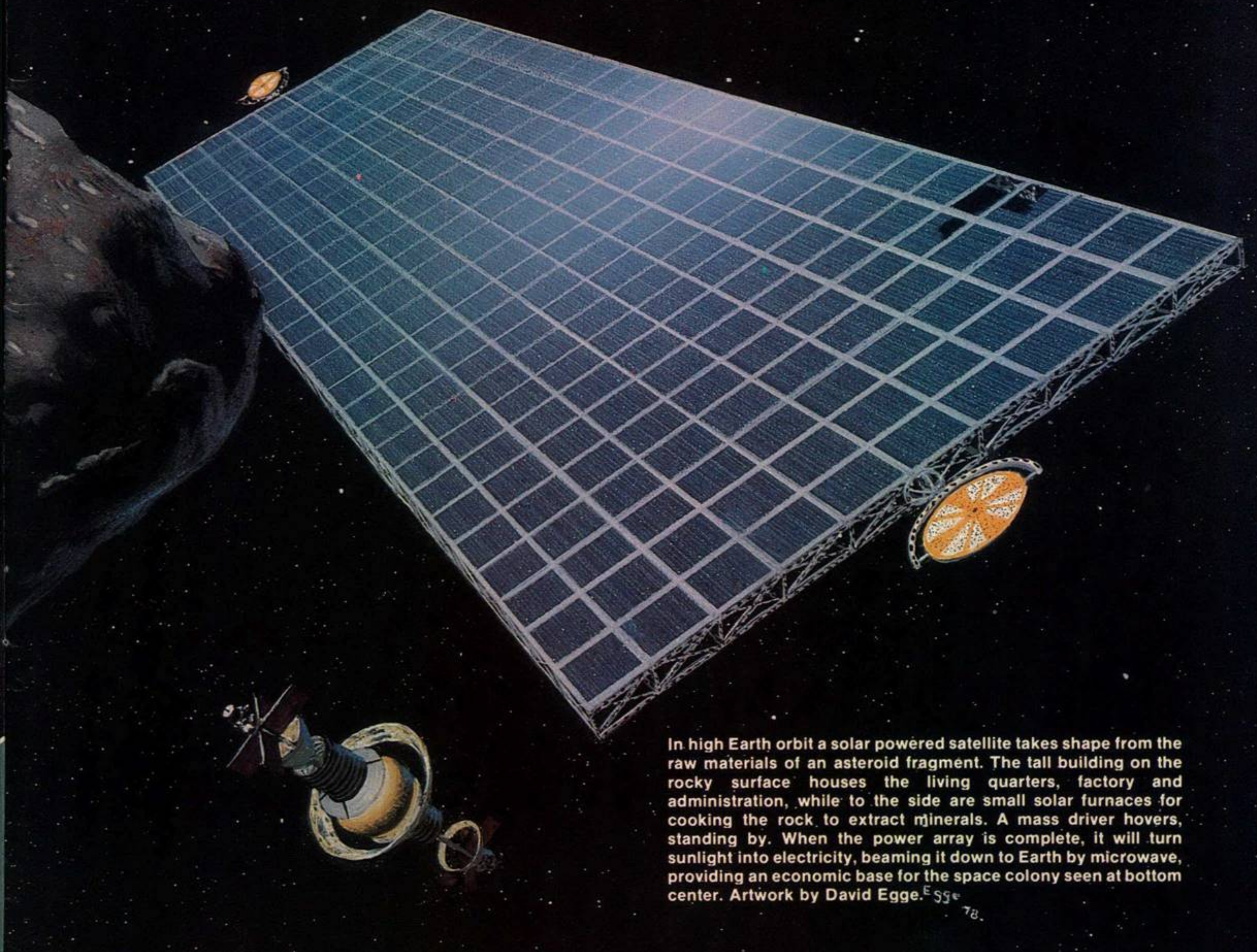
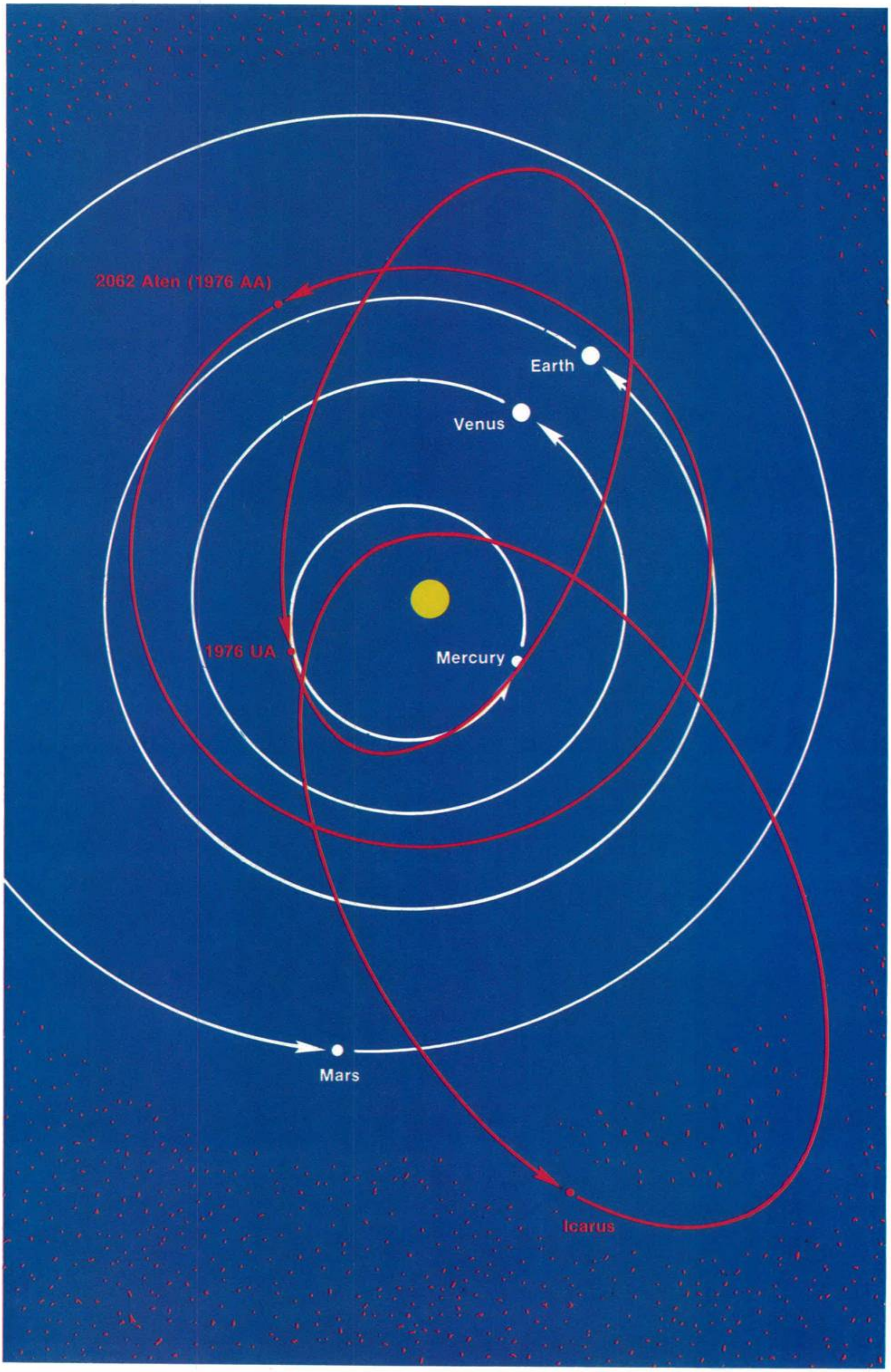


ASTEROID MINING

by
Brian O'Leary



In high Earth orbit a solar powered satellite takes shape from the raw materials of an asteroid fragment. The tall building on the rocky surface houses the living quarters, factory and administration, while to the side are small solar furnaces for cooking the rock to extract minerals. A mass driver hovers, standing by. When the power array is complete, it will turn sunlight into electricity, beaming it down to Earth by microwave, providing an economic base for the space colony seen at bottom center. Artwork by David Egge.


2062 Aten (1976 AA)
Earth
Venus
1976 UA
Mercury
Mars
Icarus

Scenario: It is 1992, 500 years after the historic voyage of Christopher Columbus. For the first time ever, humans are exploring new worlds beyond the moon, which — 23 years earlier — was visited in the Apollo program.

The astronauts this time are embarked on a much bolder venture than just landing and exploring. The crew of 12 has set up a mining operation on an asteroid! Called Columbus, the asteroid is an irregular potato shaped rock situated some 30 million miles and six months' journey from Earth at the time of landing. Columbus looks a bit like Viking photographs of the Martian moon Phobos, except that Columbus, called 1981 BD when discovered 11 years earlier, is the size of a football field across, and weighs a mere two million tons — barely the size of the smallest craters discernable on a photograph filled with Phobos.

The crew has put a bag around the asteroid and has attached it to a curiously long and skinny series of "mass driver" rockets, nudging Columbus gently toward a new path around the sun that will bring the astronauts and the prized asteroid toward Earth.

Solar collectors stick out along the noodlelike tubes of the rockets, each several miles long. By soaking up sunlight continuously to produce magnetic fields, the solar collectors provide power to accelerate the small chunks of rock inside the rocket tubes. The energy (from the sun) and reaction mass (from the asteroid) — the principal resources needed to move the asteroids from deep space into a high orbit around Earth — come for free. Sending the crew and retriever to rendezvous with the asteroid turned out to be the greatest challenge. But that was spread out over four years of space shuttle launches to low Earth orbit. After the mass driver, mining apparatus and crew quarters were assembled, the complete asteroid retriever then made the slow spiral out of Earth's gravity field on a half circle around the sun to the rendezvous point.

Now, in 1992, a small mining tractor is chewing up Columbus at the rate of 20 pounds per second. The loose agglomeration of asteroidal material is rich in carbon and water, like the carbonaceous meteorites which land on Earth. At a processing station, a large mirror concentrates sunlight, heating the asteroid dust. Valuable water and carbon are driven out by the solar furnace and saved as ice and dry ice in bags on the shady side of Columbus. Iron and nickel particles are taken out by magnets and saved, too. The rest is used as fuel for the mass driver rockets. After a three year trip, the 400,000 tons of ice, dry ice and metals brought to Earth orbit will be used by hundreds, later thousands, of people inhabiting a "tinker toy" modular space station at 2/3 the distance to the moon. The remaining million tons of Columbus will be used for further processing, habitat cosmic ray shielding, and as reaction mass (fuel) for later journeys.

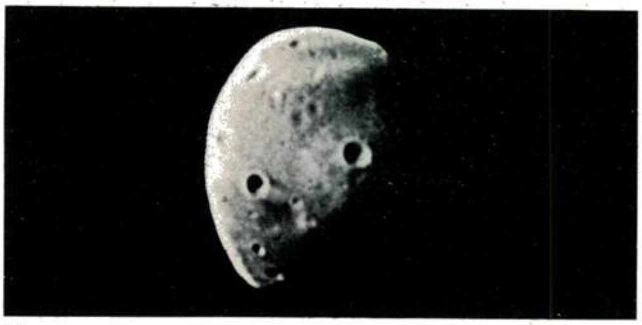
At left are three asteroids and the inner solar system. The curious varieties of asteroid orbits are shown here: Icarus and 1976 UA have elongated orbits, while Aten (1976 AA) has an almost circular path. Though the orbits appear to intersect, in reality they are inclined to each other, making collisions very rare possibilities. Diagram by Robert Burnham.

> Is this a science fiction fantasy? I don't believe so. Perhaps this scenario will not occur exactly as described in the time frame suggested. But an increasing number of scientists and engineers, living in the reality of what is possible today, have recently been studying ways in which the resources of the moon and asteroids can be used for alleviating the limitations of Earth, while opening new visions and outlets to exploration. — *Brian O'Leary*

While waiting for Columbus to arrive, new space settlers in high Earth orbit prepare to construct enormous solar collectors and microwave transmitters to supply vitally needed energy to Earth. Asteroidal materials — metals and glass processed in space using continuous solar energy — are used to build the power collectors. Even the first small asteroid will supply sufficient material to build collectors for supplying the United States with much of its increased electricity demand during the 1990s. Later, toward the turn of the century, larger asteroids will be retrieved. Nuclear, coal and oil plants can then be phased out as the primary sources of central station base-load (continuous) electricity on Earth. Asteroidal metals will replace dwindling supplies of nickel, iron and other metals on Earth. Huge agricultural stations in space, built from asteroidal materials, will grow food which will be shipped to Earth to relieve starvation and undernourishment of billions of people.

Today, Columbus Day 1992, the astronauts and their first captive asteroid are headed for a flyby of Venus. This space odyssey will put them on a trajectory toward Earth, where they will swing by just three months later. But that won't end the journey. Crews will be changed, and another year will pass before asteroid, crew and mining operation once again loop past Earth, still not to be captured! Then, after yet another crew change and one more year, what is left of the asteroid (about half), along with the extracted ice, dry ice and metals, will come in slowly, coasting into a rendezvous orbit with the space station after a gravity assist by the moon.

A game of celestial billiards will have been played: A Venus-Earth-moon gravity assist mission, taking nearly four years, will provide enough materials to fuel a new era in the exploration of space and human affairs. It will be the first purchase of nonterrestrial materials, free of the costly gravitational bondage of Earth. The limits to growth in energy, resources and food on



Deimos

NASA photograph

Earth will have been pushed back, and the door opened to the permanent human habitation and routine exploration of space.

Where Do We Stand Today?

Over the years, Konstantin Tsiolkovsky, Dandridge Cole, Arthur C. Clarke and other writers have had similar visions. But a viable solution to the challenges of mining the resources of the moon and asteroids and processing them into large, livable structures in space awaited a modern synthesis of current concepts and technologies by Princeton University scientist Gerard K. O'Neill.

Using Apollo data on the composition of materials on the lunar surface (about 40 percent oxygen, 20 percent silicon and 20 to 30 percent metals), O'Neill has calculated that the cost of retrieving lunar materials and using them to build large structures in space would be about 100 times less than lifting those same materials from the deep gravity well of Earth. In space, the abundance of energy and materials guarantee rapid exponential growth of products, relieving the stress on terrestrial resources, energy and food — perhaps just in time to avoid worldwide disaster.

But we must ask ourselves: What is needed to begin mining the moon or building a processing plant in space? First, we need raw materials. Until recently, the lunar surface seemed like the best place to go: Samples returned by the Apollo astronauts showed that lunar materials would indeed be useful. Furthermore, the lunar surface is no more than a few days' journey away. And the problem of catapulting materials from the lunar surface into free space by a solar powered mass driver appears to have been solved — at least on paper and by successful experiments with a student built model. Engineering studies (carried out by professional teams during the summers of 1976 and 1977 at NASA's Ames Research Center) concluded that lunar mining and space processing could begin during the early 1990s with an investment of approximately $60 billion. In 1978 dollars, this is slightly more expensive than the Apollo program. But the cost would be stretched out over nearly twice as long a period — 15 years versus Apollo's eight. This is equivalent to NASA's annual budget of $4 billion, or one percent of U.S. federal spending. A much smaller research and development effort, over the next few years, would be adequate to demonstrate all the required steps through tests and simulations on Earth and in space. The payback would amount to trillions of dollars.

An alternative to lunar mining is now getting increased attention — mining Earth-approaching asteroids. Asteroids are abundant, occasionally accessible (it costs little energy and money to get to and from some of them), have near zero gravity fields, and offer a wide selection of resources (including some not available on the moon). These asteroids are a competitive option to mining the moon, and far preferable to launching large quantities of material from Earth.

But first we need to learn more about them. Over the next decade, a program of scientific study is a prerequisite to mining. The Earth-approaching asteroids may offer important scientific clues about the history of the solar system, as well. And surprisingly, in terms of the amount of rocket fuel required, materials from selected Earth-approaching asteroids are easier to get than samples from the moon! Physicist John Niehoff has evaluated mission opportunities to a number of Earth-approaching asteroids. He concluded that a one kilogram sample (about two pounds) of the asteroid 1973 EC could be returned to the surface of Earth in 1980 or 1992 by one Space Shuttle payload containing a supply of propellants and a recoverable upper stage.

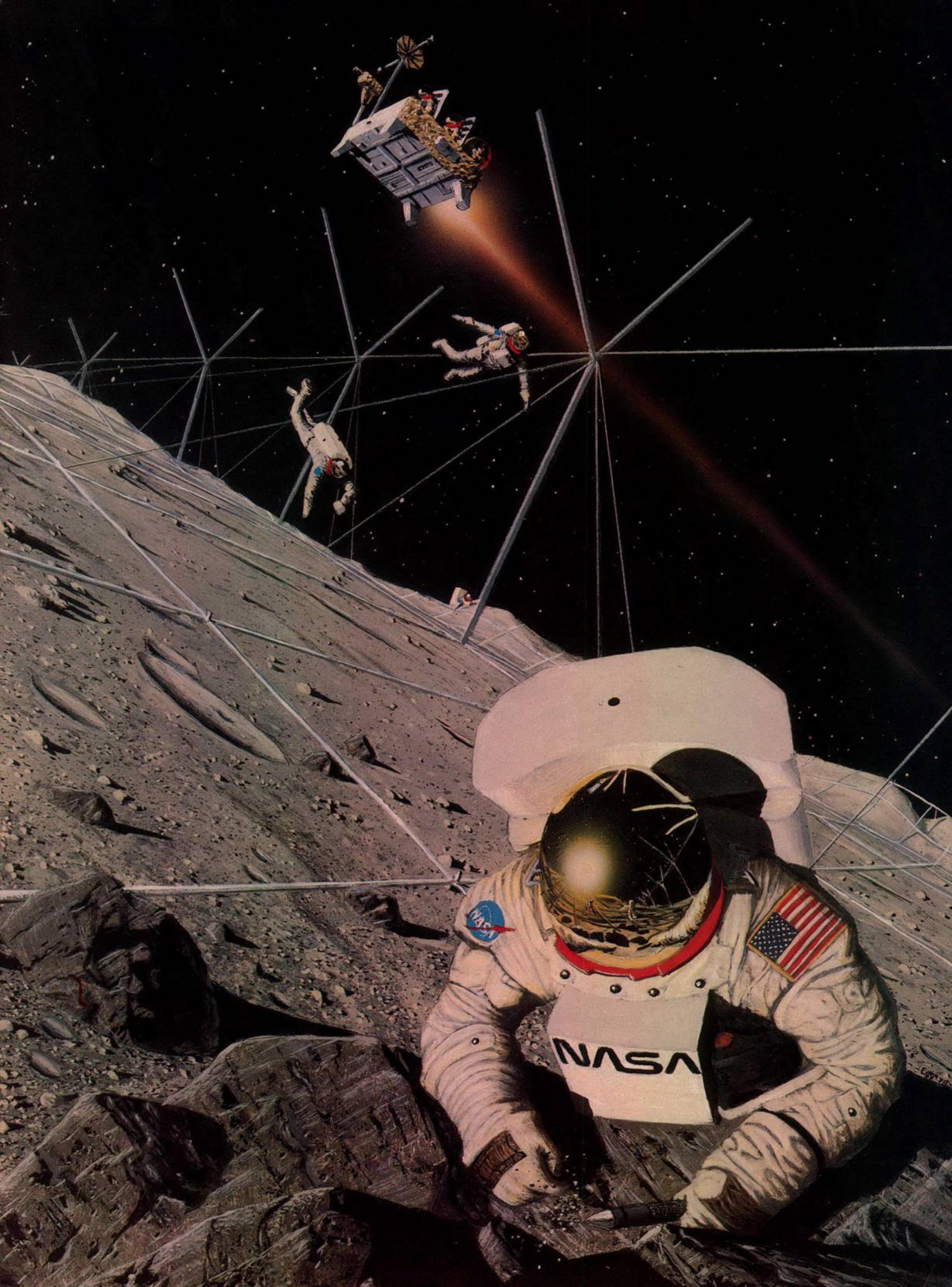
Earth-Approaching Asteroids

What do we know now about Earth-approaching asteroids? Based on their orbits, these asteroids fall into two classes: *Apollo asteroids* — whose orbits intersect Earth's, and *Amor asteroids* — whose orbits lie beyond Earth's but, at least in part, inside the orbit of Mars. The orbits vary from nearly circular to highly elongated, and are not confined to the narrow plane of the ecliptic, as the major planets are. Forty are currently known (about half in each class), and their sizes range from a few hundred meters to tens of kilometers across.

Measurements of the reflection of sunlight from these asteroids indicate that they rotate every few hours and that their shapes are highly irregular. This is not surprising because they don't have enough gravity to overcome the inherent strength of the rock holding them together. Unlike Earth, the moon, planets, larger satellites and asteroids, the Apollo and Amor asteroids are not massive enough to collapse into spherical shapes.

Most investigators believe that the Apollo and Amor asteroids have come from the main asteroid belt. Over the eons, the theory goes, they have gone astray, perturbed by the major planets into orbits closer to the sun. In recent years, astronomers have classified the chemical composition and identified the mineralogy of asteroids from Earth based telescopic observations by measuring their spectral

A scientist takes a last minute sample from an outcrop, while workmen prepare to despin a small asteroid prior to moving it from orbit. A network of cables covers the surface to prevent large pieces from flying loose during the maneuvers. Overhead zooms a rover vehicle. Artwork by David Egge.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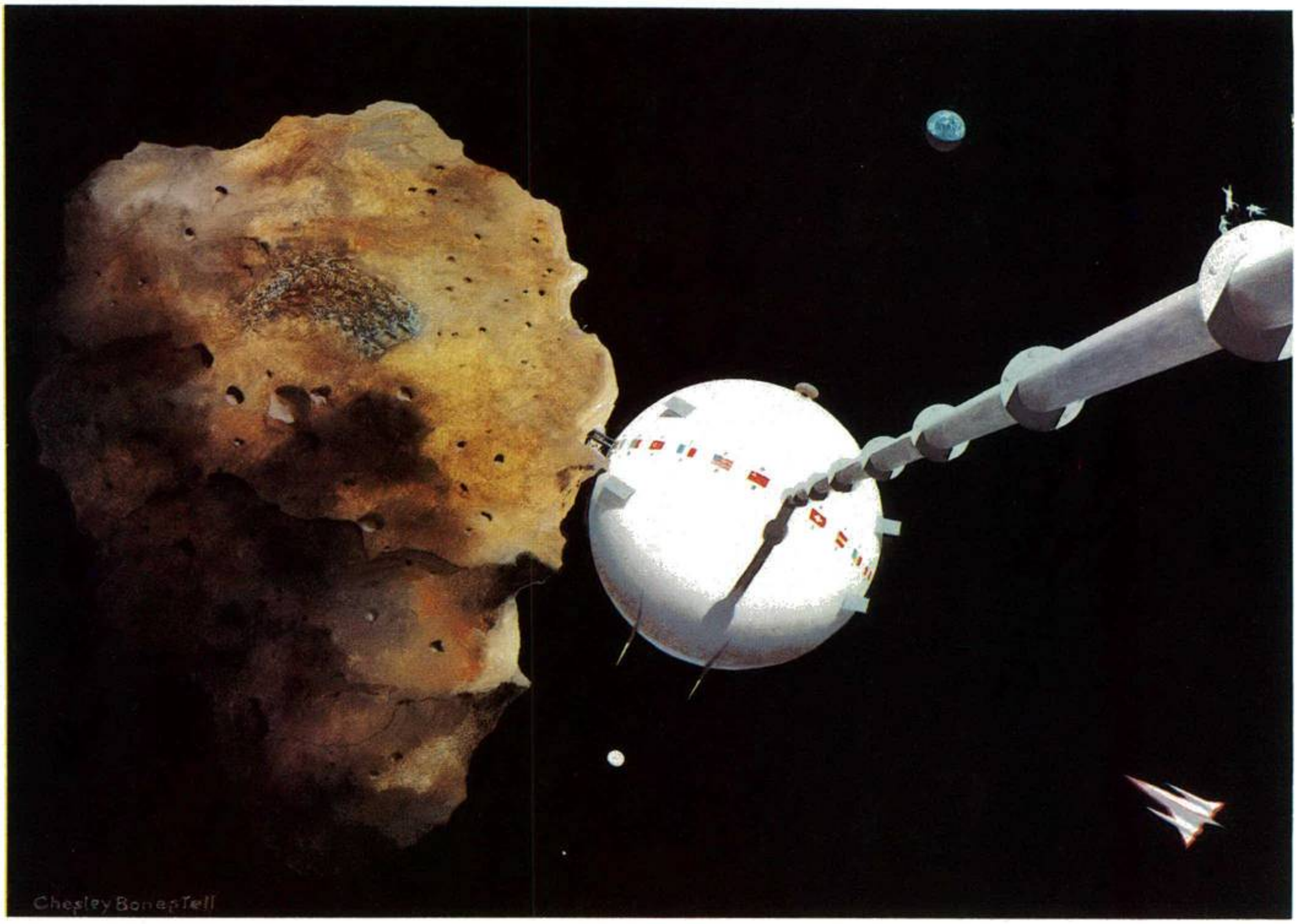


After a many-month-long journey several times around the inner solar system, the asteroid and ship arrive in Earth parking orbit. Here the asteroid will be excavated and broken down to its constituent minerals to feed Earth's growing space industries. The benefits for mankind will be twofold: First, large supplies of minerals will become available for use; secondly, the immense wealth of knowledge that will flow from direct, hands-on exploration of asteroids will certainly force us to look again at our ideas on solar system evolution. NASA artwork by Chesley Bonestell.

reflectances. These observations have been compared with results of laboratory studies of the optical properties of meteorites whose chemical and mineral content are well-known. Some asteroids and meteorites appear to fall into common groups; thus astronomers are confident that many of our meteorites came from asteroidal parents which first resided in the main belt and later perturbed into Earth-approaching orbits.

In the main belt, the matches are particularly close between one class of asteroids and *stony* and *stony-iron* meteorites, and between a second class of asteroids and *carbonaceous chrondrite* meteorites (many of whose members are water and carbon rich). The Apollo and Amor asteroids are just beginning to be looked at. At least six of them appear to be made of the same stuff as ordinary chondrites, the most common meteorites collected on Earth. But investigators believe that one of them, Betulia, may be carbonaceous.

The likelihood that some of the Earth-approaching asteroids are carbonaceous is significant. Carbonaceous meteorites have been analyzed in the laboratory. They contain complex organic compounds, including amino acids, a prime constituent of living things on Earth. Moreover, there is evidence that these objects consist of the primordial material of the solar system, making them of great interest to astronomers. Most other matter comprising the solar system outside the sun has been irreversibly altered by the separation of different elements and compounds by weight and chemical reactions. The carbonaceous meteorites which land on Earth are altered by the heat of entry into the atmosphere and by reaction with water and wind on Earth's surface, and are no longer good specimens.

So there are two compelling reasons to visit a carbonaceous asteroid in space — scientific (because these objects appear to represent the purest example of primordial material in the solar system), and prospecting (because the water and carbon resources are vital for space stations and habitats). These consumables may otherwise have to come from the deep gravity well of Earth, because carbon and water appear to be largely absent on the lunar surface.

Finding Apollos and Amors

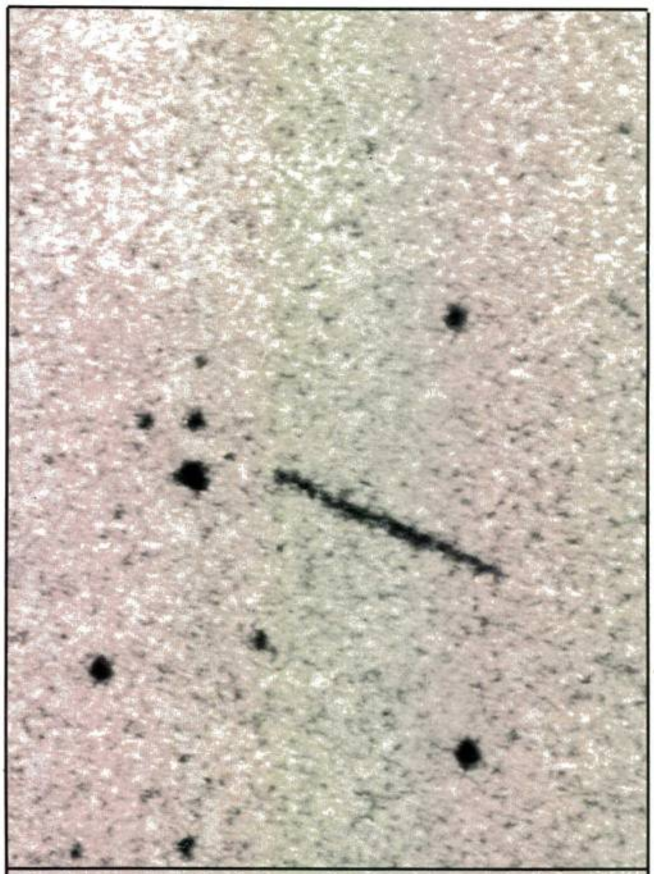
How abundant are the Apollo and Amor

asteroids, and how can we find the carbonaceous ones? Estimates of the numbers and sizes of craters on the moon and Mars, combined with data on the 40 Apollos and Amors whose orbits are known, suggest that there are at least 100,000 Earth-approaching asteroids with diameters greater than 100 meters (330 feet) and weighing a million tons. This is approximately the size we assumed in our retrieval scenario, and the size of the body which produced Meteor Crater in Arizona. Many of these asteroids are probably carbonaceous, while others are metal rich like some of the meteorites which land on Earth. These estimates are probably in error by no more than a factor of two. Clearly there are lots of Apollo and Amor asteroids waiting to be discovered.

The discovery rate is, in fact, going up rapidly. Caltech scientists Eleanor Helin, Eugene Shoemaker, Charles Kowal and their students have been finding two or three new Earth-approaching objects every year in a very modest observing program at the 18 and 48 inch Schmidt telescopes at Mt. Palomar. While taking photographs of the region of the sky opposite the sun, at times when the moon isn't there to scatter light into the telescope, they occasionally find a streak in the star field. Earth-approaching asteroids move very quickly against the backdrop of stars, so a 10 minute exposure is adequate to produce a streak on a photographic plate (see Astro-News, page 64).

As soon as they've made a confirming observation and analysis to eliminate the possibility that the streak may be an artificial satellite or an elliptical galaxy, Helin and her associates alert other observers. For the next several days or weeks, the object is photographed so that its orbit can be pinned down. Whenever possible, spectroscopist-astronomers observe its brightness and color to determine its chemical class so that, hopefully, an inference can be made on whether it is carbonaceous, stony, stony-iron, iron-nickel, ordinary chrondrite or some combination of these. All these activities need to be done within about a month of the discovery, because as the asteroid moves away, it fades in brightness rapidly. Most of the discoveries are made when the asteroid is at its brightest, directly away from the sun, fully illuminated and closest to Earth.

Those modest observing programs have yielded some interesting discoveries — for example, 1976 AA, the first asteroid discovered whose average distance from the sun is less than Earth's! Occasionally, accidental discoveries of Earth-approaching asteroids are made on photographs taken at the Mt. Palomar 48 inch Schmidt telescope (the same instrument recently used to detect an asteroid between the orbits of Saturn and Uranus). A 48 inch telescope would be adequate to detect most Earth-approaching asteroids larger than 100 meters across (the size assumed in our scenario) when they are in a position



1976 UA

Photograph by E.F. Helin

Will An Asteroid Hit Earth?

That the Apollo and Amor asteroids might be parent bodies of some meteorites which land on Earth should be no surprise. Scientists who study changes in asteroidal orbits around the sun have concluded that all currently observed Apollo and Amor asteroids will eventually impact Earth, Venus or the moon, and most of the events will occur over the next 100 million years. This is attributable to the unrelenting and uneven pull of the planets. This maximum span is 50 times shorter than the age of the solar system and projected lifetime of our sun as a stable star.

But we needn't worry about collisions during our lifetimes. The number of these asteroids is small enough that the occurrence of devastating impacts on Earth is very rare. We know this from counting the numbers of large, fresh looking craters on the moon and Mars. There simply are not enough of them to become alarmed.

Meteor Crater near Winslow, Ariz. is a possible example of impact by a small asteroid in geologically recent times. The crater resulted from the impact, about 22,000 years ago, of an iron-rich asteroid 50 to 100 meters (150 to 300 feet) across, weighing several hundred thousand tons. A more recent cataclysm in Siberia in 1908 devastated a large area and may have been the result of the impact of a comet, hypothesized as another class of parent body for objects which impact Earth.

Nobody yet knows what an asteroid would look like close up, but a good guess would make it like Mars' moon Phobos, seen here in a photo taken by Viking Orbiter I. Several lines of evidence lead astronomers to think that both of Mars' moons are captured asteroids, so the images returned have been eagerly studied by asteroid astronomers. The surface of Phobos is pitted with craters of all sizes, ranging from the large gouge (at left center) down to a regolith of pulverized rock which resembles that already sampled on the moon, and which seems to cover most planetary surfaces. NASA photograph.

in their orbits opposite the sun from Earth. In other words, many of the 100,000 estimated Earth-approaching asteroids are within reach of existing telescopes on Earth with an observing program spanning several years.

In 1977, two groups gathered in California to study what would be required to make a comprehensive survey of asteroidal resources near Earth. The unanimous recommendation of both groups was that the Earth based search and followup programs be increased immediately. A 48 inch Schmidt telescope, dedicated to this purpose, could double the number of known Apollo and Amor asteroids in just one year! About 10 years from now, we could know the orbits and composition classes of several hundred Earth-approaching asteroids.

Other bootstrapping with existing projects is likely to lead to still more discoveries of Earth-approaching asteroids. An Air Force program, designed to detect artificial satellites at considerable distances from Earth, could be reprogramed to search for asteroids at negligible extra cost. Asteroid detection will also be possible from the planned NASA infrared orbiting telescope.

Not all near Earth asteroids are good candidates for scientific, prospecting and mining missions. In fact, most of them have orbits which are too highly inclined or elongated to reach easily, and many of them lack the carbon, water and metals best suited to space manufacturing. Even the best candidates are sometimes hard to reach, because some have orbits similar to Earth's and are in the wrong position except for brief intervals once every several years. So the more asteroids known, the better the chance of finding one ideally placed for a recovery mission!

Reaching Out to the Asteroids

At least some of the 40 known Apollo and Amor asteroids *do* offer mission opportunities. Even ordinary round trip missions to asteroids 1973 EC and 433 Eros (both Amor asteroids) would require considerably less rocket power than favorably planned round trips to Mars. (Round trip time is about three years.)

Even so, a new class of asteroid missions seems to hold more promise. These missions use a gravity assist from a planet. By flying a close encounter, the trajectory of the spacecraft is altered in a way favorable to getting it to another destination. It's almost like a game of celestial billiards, where the correct glance off one ball redirects the cue ball (spacecraft) to another ball. Planetary gravity assists were successfully carried out by the Mariner 10 Venus-Mercury flyby and the Pioneer 11 Jupiter-Saturn flyby.

Using high speed computers, mission planners calulate how much fuel and cargo can be brought to an asteroid for a round trip mission in which gravity assists play a role. Recently, David Bender of the Jet Propulsion Laboratory, then on leave at NASA's Ames Research Center, discovered some low energy missions to and from some of the Earth-approaching asteroids. One particularly favorable opportunity would be the return from the recently discovered Apollo asteroid 1977 HB during the 1980s. Although this is probably too early for a retrieval mission, it does serve as an example of what is possible. Launch from Earth orbit is April 28, 1984, with arrival and rendezvous at the asteroid on Nov. 28, 1984.

After rendezvous, the material to be retrieved from the asteroid would be nudged gently toward Earth. The alteration of its orbit would take nearly two years, using solar energy to power either an ion engine or mass driver rocket. On April 15, 1987, the retriever spacecraft would pass close to Earth.

However, the spacecraft would be traveling too fast to be captured by Earth's gravity field. At that point in the mission, the spacecraft would be targeted to a point where Earth's gravity field would swing the cargo toward a seemingly unlikely destination: Venus.

On March 10, 1988, there would be a close encounter with Venus, returning the spacecraft to Earth's vicinity for an August 1988 arrival. This time its speed would be lower, but still not low enough to be captured. Thrusting all the time, the rocket would make one more circuit around the sun. Its odyssey would end on Sept. 28, 1989, as the moon captured it in a convenient orbit high above Earth. Although the return trip would take nearly five years, the investment in rocketry would be surprisingly small!

1977 HB is but one of thousands of potential possibilities. Our knowledge of the chemical and physical properties of Earth-approaching asteroids is sufficiently uncertain that it will probably be necessary to send advance missions to prime candidates for *in situ* analysis, or possibly sample return to Earth.

A program of unmanned missions to rendezvous with the best candidates, selected for their favorable orbital and chemical characteristics, was recommended by the two study groups which gathered in California in 1977. Scientists at the La Jolla Workshop on Near-Earth Resources recommended a NASA fiscal year 1980 new start on hardware development specifically geared to chemical and physical analysis of the best candidate asteroids in a series of missions planned for the mid-1980s. The precise priority of targets need not be known until some months before launch, pending constant revision as new discoveries are made, orbits are determined, and chemistry and mineralogy are classified.

We're Already Mining Asteroids

As futuristic as it may sound to be thinking of using resources from the asteroids, a little known fact is that we are probably already mining an Earth-approaching asteroid! In Ontario, Canada, a large circular area called the Sudbury astrobleme is likely to have come from the prehistoric impact of a giant iron-nickel asteroid. During the 1960s, this region produced about 1/2 the world's nickel supply.

Exploiting the Asteroids

Advance missions would pave the way for resource retrieval missions to the asteroids as early as 1990. It's still early to tell exactly how those missions would be carried out. Our scenario represents an educated guess of one possible mining operation. It seems likely, too, that the asteroid scenario would be more cost effective than the lunar scenario during the first years of space processing in the 1990s. But the preliminary work of discovering candidates and going to sample them must be done first, and it has already been done on the moon.

Building satellite power stations, space habitats, large food-growing areas and manned planetary explorers are not the only possible uses for the materials from near-Earth asteroids. Astronomers Michael Gaffey and Thomas McCord have suggested that an iron-nickel asteroid could be cost effectively recovered to replenish the world supply of those metals. These metals could be safely recovered from the ocean after reentry if they were made into a metal foam which would float.

An increasing number of investigators are beginning to believe that the use of nonterrestrial materials for alleviating the global limits to growth in energy, food, natural resources, population and pollution is an idea whose time has come. Space offers vast supplies of energy and materials, and these could become available to humanity — using currently available technology — with high yields beginning in the 1990s. Today Earth-approaching asteroids offer an abundant and versatile resource which might contribute to the start of an exciting new era in human endeavor.

Dr. Brian O'Leary is on the research faculty in the physics department at Princeton University. An ex-astronaut, he received his Ph.D from the University of California (Berkeley) in 1967. He has been deeply involved in many aspects of planetary science, with his most recent research centered on the economic potentials of Earth-crossing asteroids.

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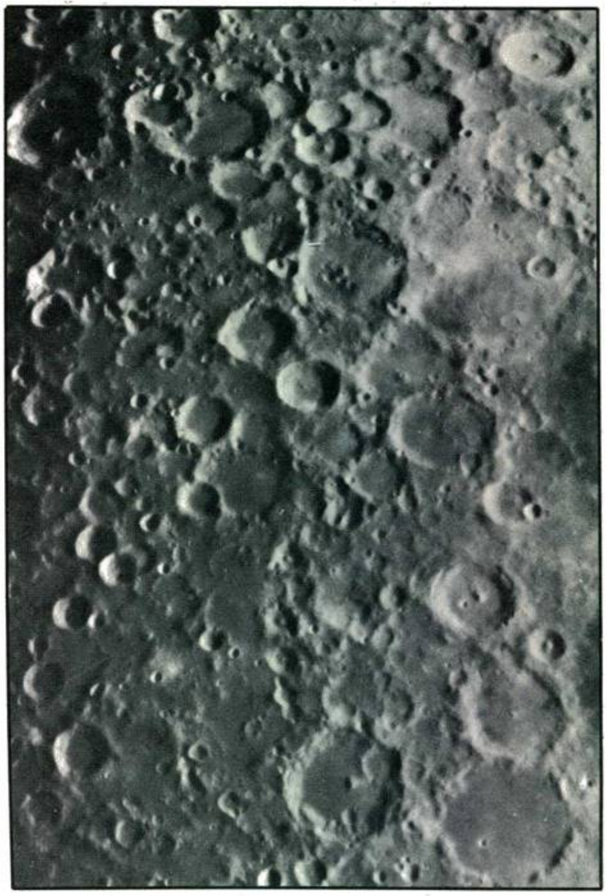

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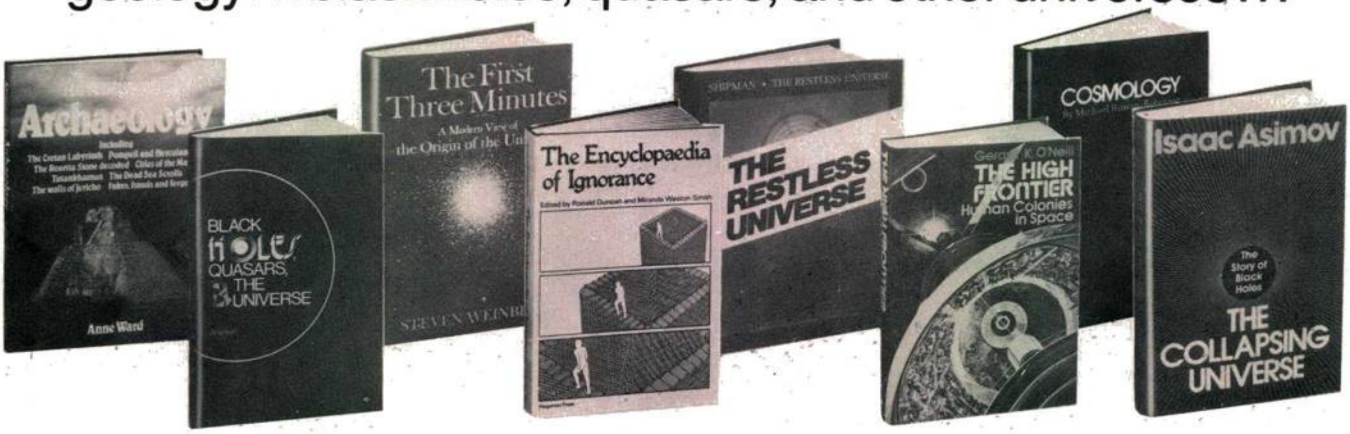

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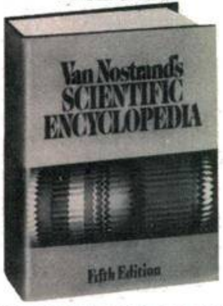

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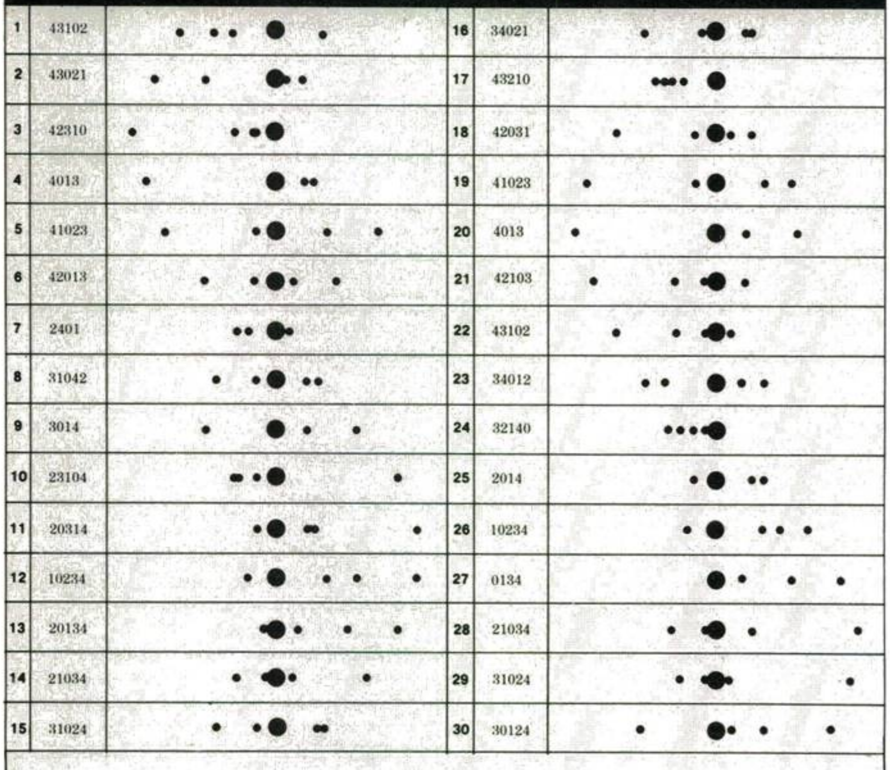
Meteors, Mercury and Morning Stars

by

Robert Burnham

Planet watching this month may be hard on observers, because it means getting up early! All the action has shifted from the evening sky into the morning, with the exception of an elongation of Mercury. Venus moves into the morning sky starting about the middle of the month; Saturn has been there for the last two months or so, and even Jupiter still makes anyone who wants to see it get up in the early morning hours. On top of this, there are two meteor showers and a late evening occultation of Aldebaran. So bundle up and get out there!

November Satellites of Jupiter
09:00 UT, 05:00 EST, 01:00 PST



1	43102	16	34021
2	43021	17	43210
3	42310	18	42031
4	4013	19	41023
5	41023	20	4013
6	42013	21	42103
7	2401	22	43102
8	31042	23	34012
9	3014	24	32140
10	23104	25	2014
11	20314	26	10234
12	10234	27	0134
13	20134	28	21034
14	21034	29	31024
15	31024	30	30124

The four major satellites of Jupiter orbit the planet in periods ranging less than 2 days to 17 days. You'll see them change position from night to night. This table shows the approximate position of the moons each night. The column at the far left shows the date; the second column gives the names of the moons (Jupiter = 0, Io = I, Europa = 2, Ganymede = 3, Callisto = 4). The third column shows the satellites' positions as they appear through an inverting telescope; south is at the top.

Mercury

The evening hours will present an elongation of Mercury this month, but for northern hemisphere observers the apparition won't be very good.

The maximum elevation will be only nine degrees! The actual elongation occurs on the 15th, but you should be looking from the 17th to the 21st to catch maximum elevation. (Why? It's due mainly to the interaction of angles: Mercury's orbit, the horizon, and the sun's declination.)

Telescopically, Mercury will appear as a disk seven seconds of arc across on the 19th, looking very much like a tiny first or last quarter moon. But if you look for detail, don't expect much! The thick, soupy atmosphere and generally poor "seeing" guarantee that visual observations of surface detail will be highly uncertain.

Each day during the month, you'll notice its brightness change steadily. Beginning at magnitude -0.2 on the 1st, it will drop 1/10 magnitude by

The dramatic conjunction of the moon and Venus is shown in this photo taken Aug. 7, 1978 as the pair set. The moon's eastward motion in the sky reveals itself as it bypasses Venus: Compare the relative positions in the earliest picture (upper left) and the last (lower right). Exposures lasting four seconds at f/8, at eight minute intervals on one frame, gave the pretty result. The film was Vericolor II-S. Photograph by Bill Sterne Jr. and Paul Mitchell.

the 13th, and lose another 3/10 (to +0.2) by the 23rd. Finally, by the 30th, it will be down to +1.0.

If you want to catch Mercury, you'll have to work fast. By the end of November the planet will be racing toward inferior conjunction and perihelion, both of which come just a day apart in early December.

Venus

Venus passes between Earth and the sun on Nov. 7, and then starts climbing into the morning sky. You won't begin to see it clearly until about the 15th or so, but try looking as soon after the 7th as weather allows! On the 15th you'll see it 9 to 10 degrees high in the southeast at sunrise.

Venus will change in magnitude from -3.0 at inferior conjunction (it's then five degrees south of the sun, but lost in the glare) to -4.2 by the end of November. Look for it every clear morning and you'll have no trouble spotting and following its daily movements.

On the 15th the planet will be just over 60 seconds of arc diameter. Between then and the end of the month, its movement away from Earth shrinks the size to about 50 seconds. Even though it gets smaller, the planet paradoxically grows in brightness. As it moves to one side of the sun, we see more and more of the sunlit hemisphere, which at inferior conjunction is facing away from us. Eventually the two effects balance, and that point (coming in mid-December) is when Venus reaches its greatest brilliancy.

Moon

On the night of Nov. 15-16, the moon, two days past full, will occult first magnitude Aldebaran. Listed in star catalogs as Alpha Tauri and seen at the eastern edge of the Hyades star cluster, Aldebaran is the brightest star the moon can occult. In a way, this is a rerun of the occultation that happened back in September, but now it's more conveniently timed for North American observers.

Weather permitting, most of our readers will be able to see the event because almost all of the United States and Canada lies between the northern and southern limits for the occultation. Those left out are in Florida south of a line between Perry and the northern city limits of Jacksonville, and all Alaskan and Yukon observers unless they live south of a line between Katalla, Alaska and Barlow, Yukon Territory. Hawaiians, too, are out of luck.

Because the moon travels from west to east in its orbit, the event happens earlier for western observers. On the Pacific coast, the time of disappearance will be about 6:45 p.m. PST. In the mountain region, the event happens at about 7:45 p.m. MST. The central time zone will see it around 8:45 p.m. CST, and in the east the time will be 10:00 p.m. EST. The Canadian Maritimes will see it a little before midnight.

Remember that all times given here are rounded off early! Because of the wide geographical spread of each time zone, we can't publish detailed predictions for each location. You'll have to go out as it gets dark and take careful note of where the moon and Aldebaran are in relation to each other. The moon moves through its own diameter in about an hour, so judge the time of occultation for *your* site accordingly!

Upcoming Events for December

5	Mercury at inferior conjunction
6	Mercury at perihelion
7	First Quarter Moon
9	Neptune in conjunction with the sun
14	Venus at greatest brilliancy
	Geminid meteors
	Full Moon
22	Solstice — winter begins
	Last Quarter Moon
	Ursid meteors
24	Mercury at western elongation
26	Occultation of Venus
28	New Moon
31	Venus at perihelion

The Geminid shower is a strong fast one, but as happens in November, moonlight will interfere. Still, it's one of the year's best, so try anyway!

The morning elongation of Mercury is a very favorable one, since the planet will climb 15 to 20 degrees above the horizon at sunrise. Venus will be 25 degrees away from it in the sky. (We'll have a chart showing positions of both in next month's Gazer's Gazette.)

The occultation of Venus will be an early morning event for the eastern 2/3 of the continent, and will be *very* pretty!

About an hour after Aldebaran disappears behind the western limb of the moon (the eastern limb in the astronomical sense), you'll see the star pop out again on the other side. (The closer you are to the northern or southern limits mentioned above, the shorter will be the duration of the occultation.) The reappearance is always tricky to watch because you never know just where on the limb the star will reappear. Perhaps using a low power eyepiece, or even binoculars, would be best since then you can scan the whole dark limb at once. Even so, you'll probably blink at just the instant it pops back!

Mars

Mars shines at magnitude +1.6 this month, but you'll not find it easily in the bright twilight sky. Low in the southwest, it'll be two degrees south of Neptune on the evening of the 26th. Neither of them can be seen well, though, since the sun is only 15 degrees away at the time.

Jupiter

Jupiter now rises some two hours before local midnight, and you'll find it in eastern Cancer. Gleaming at magnitude -1.9, you can't mistake it as there are no stars in the vicinity nearly as bright.

On the 10th, Jupiter will be exactly five astronomical units from Earth (465 million miles, or 750 million kilometers), making the 142,600km diameter planet appear as a disk 36 seconds of arc across the equator.

For Galilean moon watchers, be sure to look on the night of Nov. 11-12, when the four will be lined up from west to east in numerical order! West of the planet will be satellite I, Io. Then to the east, from the ball outward, you'll see II (Europa), III (Ganymede) and IV (Callisto).

Jupiter will glide past Delta Cancri on the night of Nov. 4-5, missing the star by 20 minutes of arc. Delta, also known as Asellus Australis (the southern donkey), is a yellow-orange star of magnitude 4.05, so it'll be about 1-1/2 to 2 magnitudes brighter than the Galilean moons. In a medium to low power eyepiece the slow passage will be fascinating to watch. Start looking a day before and continue a day after. (Where's the northern donkey? That's Gamma Cancri, which lies as far to the north-northeast of the Beehive cluster as Delta is to the south east of it — 1-1/2 degrees.)

Saturn

Look for Saturn in south central Leo, making it definitely a morning object. It now rises around midnight and will be shining at magnitude +1.1 during the morning hours. This month the ring system spreads out over nearly 40 seconds of arc, while the ball is more than 15 seconds across.

Many people have seen Jupiter's Galilean moons; not so many have seen Saturn's brighter moons. They aren't as easy as Jupiter's, but they're not as difficult as people sometimes imagine. Titan, the brightest, gets almost as bright as the dimmest of the Galilean moons. For the others you'll need a telescope, but they can be easily found at the times of elongations. Try hunting for these three:

Titan (magnitude 8.9) will be at eastern elongation on the 4th and 20th, and at western elongation on the 12th and 28th. It's separated from the planet by about 4-1/2 ring diameters

Centaurus and part of Crux are featured in this beautiful photo taken from Hawaii. Just above the center of the picture is the fuzzy spot marking the massive globular cluster Omega Centauri, while Crux pokes its northern regions over the horizon at lower right. This was a five minute exposure at f/1.4 using a 50mm lens on Ektachrome 200 film. Photograph by Ray Fabré.

then. *Rhea* (magnitude 10.3) will be to the east of Saturn on the following dates: Nov. 3, 8, 12, 17, 21, 26 and 30. The elongation separation for Rhea will be about two ring diameters. Western elongations of Rhea happen, naturally enough, halfway in time between the eastern elongations. *Iapetus* has a strange peculiarity: It's five times brighter (1.75 magnitudes) at western elongation (magnitude 10.5) than at eastern (magnitude 12.3)! November has one western elongation for Iapetus, on the 4th, but you'll have to wait until Dec. 16 for an eastern elongation to compare it to. Because Iapetus orbits Saturn at a distance of 2 million miles (3.6 million kilometers), it takes almost 80 days to go around the ringed planet once!

Uranus

Uranus is too close to the sun to be observed this month — conjunction occurs on the 9th.

Neptune

Neptune is also close to the sun and hard to see. As mentioned earlier in connection with Mars, there will be a twilight conjunction of 8th magnitude Neptune and +1.6 magnitude Mars on the 26th.

Taurid Meteors

The Taurids aren't one of the year's more prominent showers. However, this year's appearance will likely be better than the month's other, often more impressive, shower — the Leonids (see below).

The Taurids are slow meteors, averaging about 25-30km per second, and the activity is spread out over several weeks. Most showers, by comparison, peak quickly and fade. You can expect to see Taurids anytime from late October to late November, with the peak activity falling on two days: the 4th and 13th. The second peak isn't as strong as the first, and this month moonlight will interfere with it.

The maximum hourly rate for a single observer is about 15 meteors, so don't expect to see them every few seconds! Look toward a part of the sky about 10 degrees south of the Pleiades. Since the moon will be at first quarter on the 7th and full on the 14th, the early, stronger, peak will be undisturbed. Remember to start your watch for them after midnight and carry on until dawn (or as late as you can stand it!), for those are the hours when the activity is heaviest.

Leonid Meteors

This year's shower will likely be a poor one for the Leonids, which peak on the morning of the 17th, just three days past full moon. The probable hourly rate will be 15 to 20, but the actual numbers arriving have been extremely variable over the years. Whatever the outcome this year, moonlight will contaminate the results severely.

During the last century the shower gave very strong displays at intervals of 33 years: The 1833 and 1866 events were very striking. The 1899 return was poor because the main cluster of meteoroids producing the "storm", the remains of an old comet, was shifted in its orbit, making the display thin.

The 1932 and 1933 displays were better than average (up to 60 per minute), and the 1966 return was unbelievable — at one point they were arriving at an estimated rate of over 2,000 per minute! The 1999 return will be watched with great interest to see if the swarm is back to its old strength. In the meantime, every display of the Leonids should be watched carefully, for there's no assurance that the old 33 year period for great displays has, in fact, returned.

OBSERVING EARTH FROM SPACE

by
Henry W. Brandli

Some of the most spectacular photos of Earth have been taken from manned spacecraft; however, the most useful pictorial information on a day-to-day basis has been received from unmanned weather satellites. Many of these meteorological photos have also been spectacular to the trained eye of weathermen, who well know that "beauty is in the eye of the beholder".

The first meteorological satellite was launched by the United States on April 1, 1960. Since then, the U. S. space program has accomplished a great deal: We've put men on the moon and returned them safely to Earth. We've made great advances in space exploration, communications and space hardware, as well as systems to support such ventures. The computer business has boomed. Meteorological satellites have also advanced significantly since that April Fool's Day over 18 years ago.

The U. S. Weather Bureau, now called the National Oceanic and Atmospheric Administration (NOAA), has its own satellite service — the National Environmental Satellite Services (NESS). The Department of Defense (DoD) initiated its own meteorological satellite program — the Defense Meteorological Satellite Program (DMSP) — to provide a better quality and more responsive system than was available from NOAA. The DoD has a worldwide operational responsibility, whereas NOAA doesn't.

Types of Weather Satellites

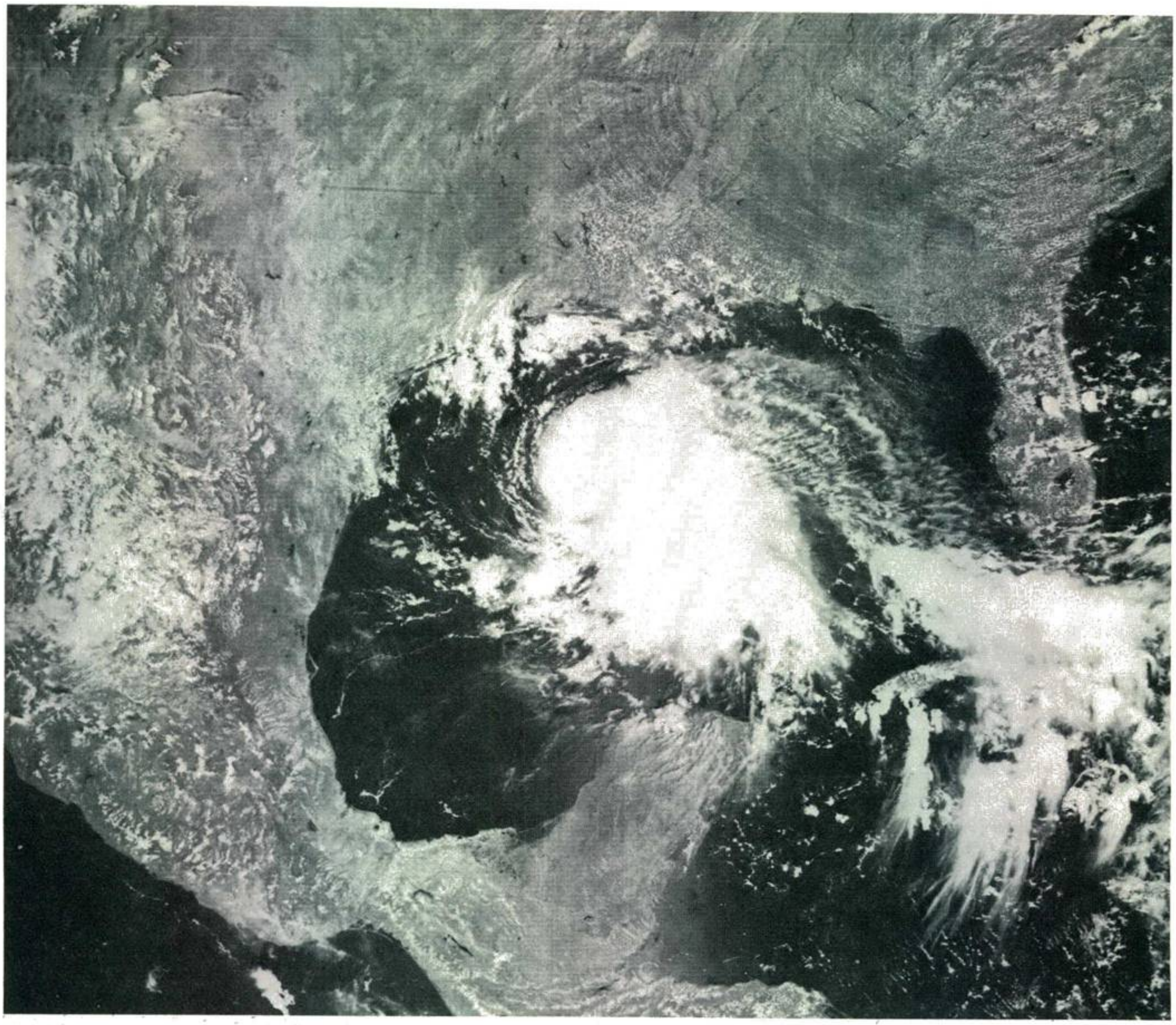
There are basically two types of satellites that provide data — largely in the form of pictures — used by meteorologists. They are polar orbiting or *sun synchronous* and *geostationary* vehicles.

Sun synchronous meteorological satellites are in polar orbits around Earth and look down on the same areas of Earth at the same local sun time every day. For example, meteorological satellites such as those operated by NOAA see the southeast U.S. on their north to south path every morning at around 10 a.m. Because the NOAA satellites are in polar orbit, they will also pass over the southeast U. S. around 10 p.m. At night, however, they "see" with infrared sensors. Polar orbiting altitudes for U.S. meteorological vehicles range from 450 nautical miles (nm) high for the DMSP to 600 nm for NASA's, to 800 nm for NOAA satellites. The advantages of polar orbiting meteorological satellites are daily global coverage, near constant viewing height, and very high and nearly constant resolution.

The Russian meteorological satellites in polar orbits are not sun synchronous, so they "see" various parts of the world at different times each day. Their altitudes range from 300 to 600 nm.

The other common type of meteorological satellite is the geosynchronous vehicle in an equatorial orbit (19,300 nm) moving at the same angular velocity as Earth's rotation. In this path, the satellite appears to remain stationary over one spot above the equator. The downward looking sensors view Earth's disk and cover almost 1/6 the globe. While above the Amazon Delta in South America, Synchronous Meteorological Satellites (SMSs) can view the U.S. continuously. These satellites are now called Geostationary Operational Environmental Satellites (GOES). These geostationary platforms are ideal for monitoring weather phenomena that occur at low latitudes — like hurricanes and typhoons. Dramatic movie loops made from the picture frames show spectacular weather movements, development and dissipation through time lapse techniques.

The Great and Little Bahama Banks lie close to the surface of the Atlantic Ocean in the left side of this picture. Photography from satellites — in this case from a Gemini spacecraft — has helped oceanologists and ecologists in their study of it. Sun glints off water around the Florida Peninsula, but the Keys and Okeefenokee Swamp are still visible under a partial blanket of clouds. Parts of the spacecraft and its antenna are seen in the bottom of the frame. NASA photograph.



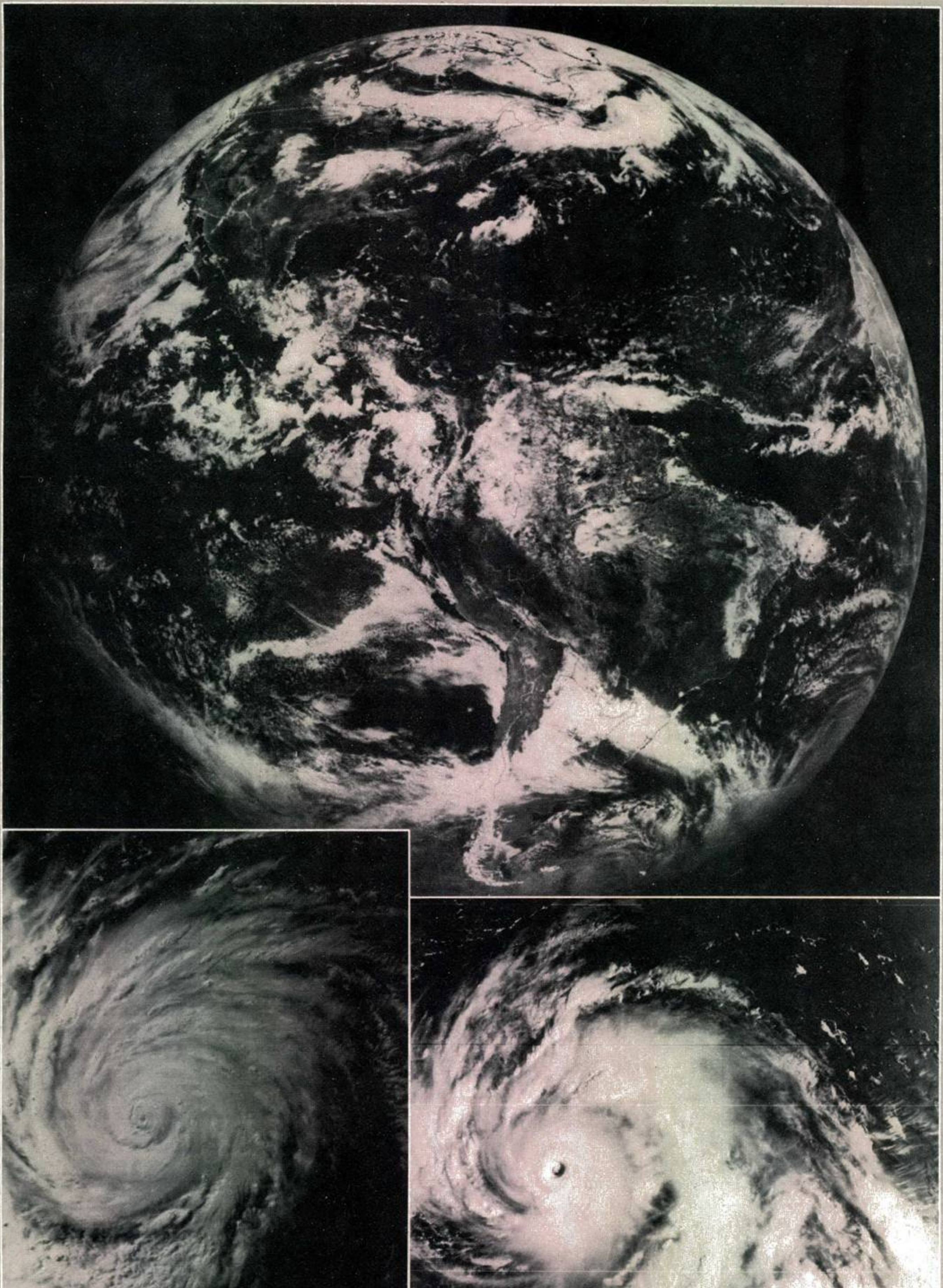
An obvious disadvantage of geostationary meteorological satellites is that two vehicles would be needed to see hurricanes in the Atlantic and typhoons in the western Pacific. Another disadvantage is that the resolution is lower at temperate latitudes than near the equator. Also, the greater distance of the geostationary satellites allows only relatively poor infrared resolutions. Soon this disadvantage will be corrected with improved technology.

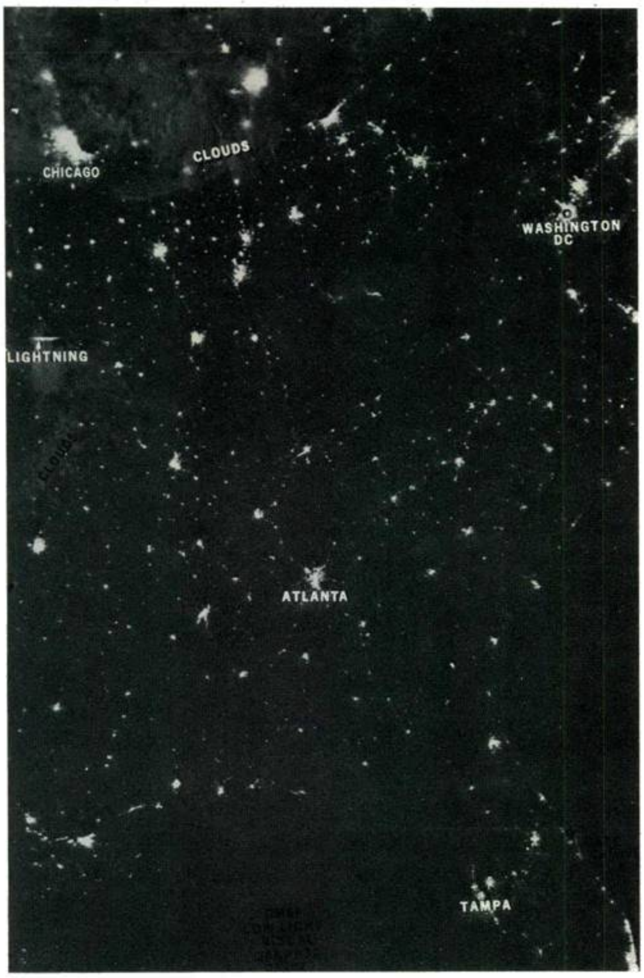
Types of Photos Transmitted

Most of the data provided by meteorological satellites is in the format of photographic imagery — pictures. The imagery, which is received either locally by ground stations or in a stored mode by weather centrals, is usually *visual* or *infrared*, or both.

The most commonly used cameras/sensors on board meteorological satellites are those which record black/gray/white visible imagery. Basically, they make black and white images (which are much cheaper than color photography) using ordinary light such as human eyes see. For meteorological purposes, color is not necessary. White is clouds, snow, ice and even sand. Vegetation is shown in shades of gray. Some forms of clouds are also gray. One of the primary concerns, at least meteorologically, is the presence or the absence of clouds. The newer meteorological satellites, particularly the DMSP ones, have expanded their wavelength coverage beyond "visual" to see better land/water contrasts as well as expanded cloud extent. Human eyes sense energy in the spectral interval from .5 to .7 microns, while the newer sensors "see" out to 1.1 microns wavelength.

Above: Earth stands out as a globe in this GOES weather satellite image of the western hemisphere. Both North and South America, and a bit under half of the planet's weather, are visible in this single view. The political map grid is computer generated. Opposite, top: Seen with stunning clarity, hurricane Anita spins into the Gulf of Mexico on Aug. 31, 1977. You might have seen this picture on the evening weather forecast last year; television, however, can only begin to hint at the quality of modern satellite imagery. Lower left: Supertyphoon June — with wind speeds up to 200 m.p.h. — was recorded from a weather satellite 500 miles high on Nov. 19, 1975. Lower right: Note the extraordinary detail in the swirling clouds of typhoon Phyllis, off the coast of Japan. NASA photographs.





Just after midnight on April 28, 1977, the Block 5-D satellite photographed the eastern United States. City lights are evident, mapping out the distribution of people and industry; in addition, some major highways can be spotted. U. S. Air Force photograph.

Including the near infrared allows better detection of chlorophyll in green plants.

In addition to daytime visual imagery, the DMSP satellite also records nighttime visual imagery. Its low light sensor "sees" by the light of the moon. If there is moonlight — at least 25 percent illumination — the clouds will be illuminated. If there is no moon, city lights, fires, oil fields, lightning, volcanos and other phenomena like the aurora borealis will be depicted.

In addition to visual imagery, many of the meteorological satellites of DoD, NOAA and NASA take *infrared* images which depict temperatures. In meteorological infrared photos, the processed images show high, cold cloudtops as white, lower cool cloudtops as gray, and hot or warm land/water as black. Six, 16 or even as many as 64 different shades of gray can be presented to show different cloudtop levels on land or water surface temperatures. This scheme can be reversed (black equals cold), and even color film can be used to show red ocean currents of certain temperatures or blue clouds. The color technique is expensive, however, so it is usually not used in an operational environment. Once calibrated by conventional thermometer readings, these images provide vast amounts of information.

Spying on Weather

Much has been written on the subject of space weather observation. Here, however, we'll only briefly touch some of the highlights of weather visible on satellite photos.

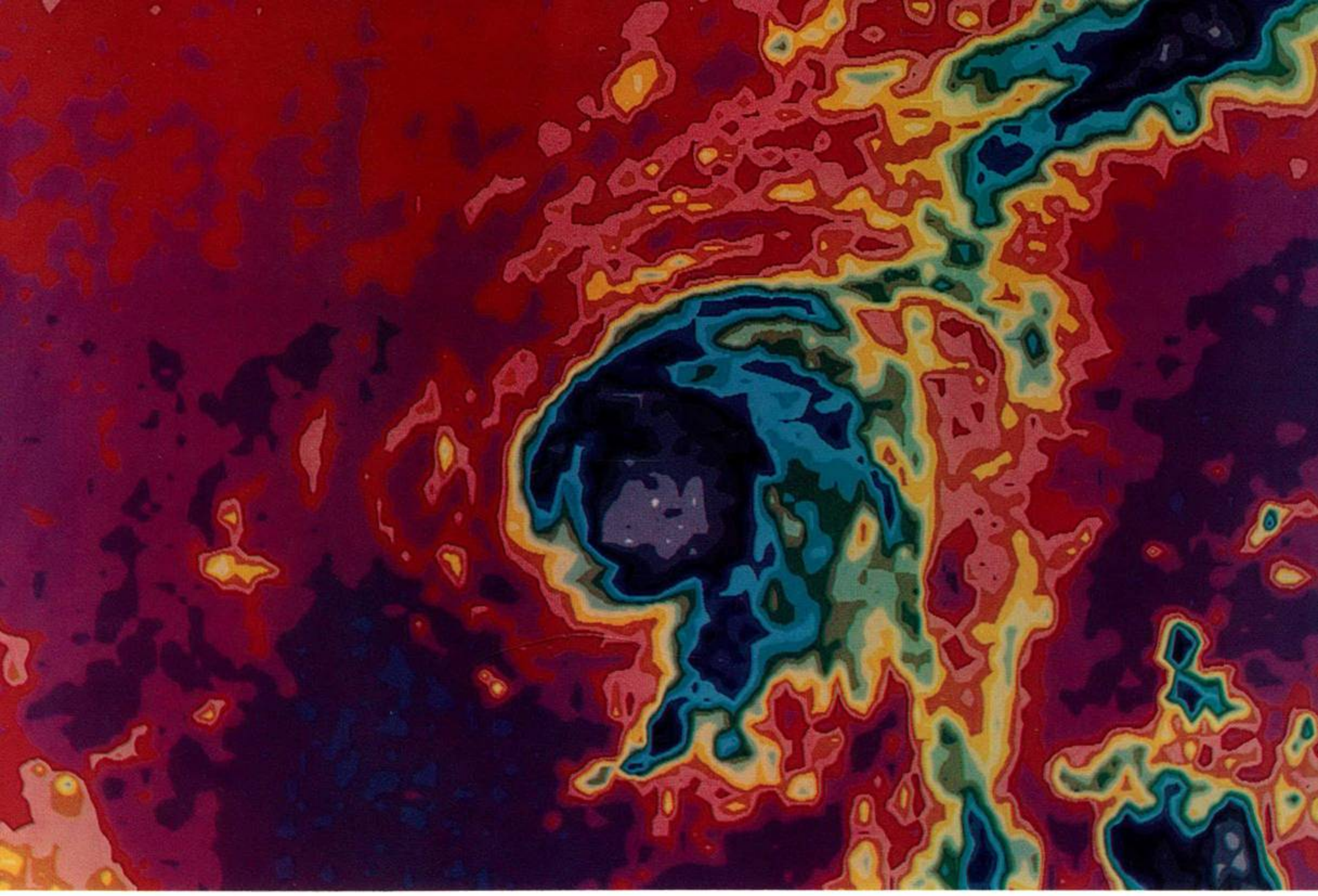
High quality near real time satellite imagery is easy to understand: Clouds are white. Clouds, cloud extent, cloud movement and — using gray shaded infrared images — the heights of cloudtops are easily seen on a series of satellite photos. Severe weather such as intense fronts, squall lines and individual thunderstorms stand out. Typhoons and hurricanes, by their very size, severity and movement, leave very little to the imagination! These meteorological satellite images "tell it like it is" — even to the public seeing the nightly picture on television.

The most common meteorological features seen on satellite photos are clouds and cloud systems. The accurate location and recognition of cloud types can be accomplished by a satellite meteorologist. This knowledge can be quickly and easily conveyed to the military or civilian customer by identification marks right on the photos. Cloud types, such as low level stratocumulus, stratus and cumulus, as well as higher clouds of cumulonimbus (thunderstorm) and cirrus along with their associated weather related phenomena (wind, rain, hail, icing, etc.), are seen on the photos in a "real world" and obvious manner. And of course, a series of pictures shows movement, development and dissipation of clouds quite vividly.

Fronts (cold, warm and occluded) are also vividly shown on satellite pictures because they produce distinctive cloud patterns. It's also possible to see thunderstorms and lightning in the frontal cloud bands! These areas of severe weather are important for aircraft missions and flights — as well as civilian populace alerts. Even tornadoes, although not seen directly on the satellite images, can be suspected quickly and correctly because of the distinctive appearance and changes in associated clouds! In this type of severe weather work, frequent images (spaced 30 minutes or less apart) are a boon to the analyst in the U. S. along with his other information. In areas where frequent images of the desired resolution are not available, radar will still be needed for certain weather observation and forecasting.

Hurricane and typhoon monitoring by meteorological satellite imagery has been a huge success over the last few years. Because satellites can provide real time data every six hours or less, using aircraft to explore and probe these storms has been re-evaluated. Satellite data now being recorded lets us track storm centers, storm extent and storm movement — with correctly gridded and interpreted weather satellite data — more easily than ever before.

Near the equator a wide band of layered clouds



Hurricane Camille was recorded in false color thermal imagery on Aug. 18, 1969. Each color band represents a different range of cloud temperatures; bright red is about 70 degrees Fahrenheit, while dark blue is -40 degrees Fahrenheit, in the high central clouds of the storm. NASA photograph.

and embedded cumulonimbus nearly encircles Earth. This cloud system is called the Inter-Tropical Convergence Zone (ITCZ). It is a danger zone for aircraft and ships. Monitoring this nearly perpetual cloud band is an ideal job for the satellite meteorologist, since the area concerned is over sparsely inhabited and remote areas. The cloud layers and thunderstorms extend vertically to over 50,000 and sometimes 60,000 feet high. Not only must the accurate mapping of the ITCZ be accomplished, but the rapid dissemination of this information also must receive a high priority. Planning routes and diversion for ships and planes through these areas is a relatively easy task for present satellite meteorologists.

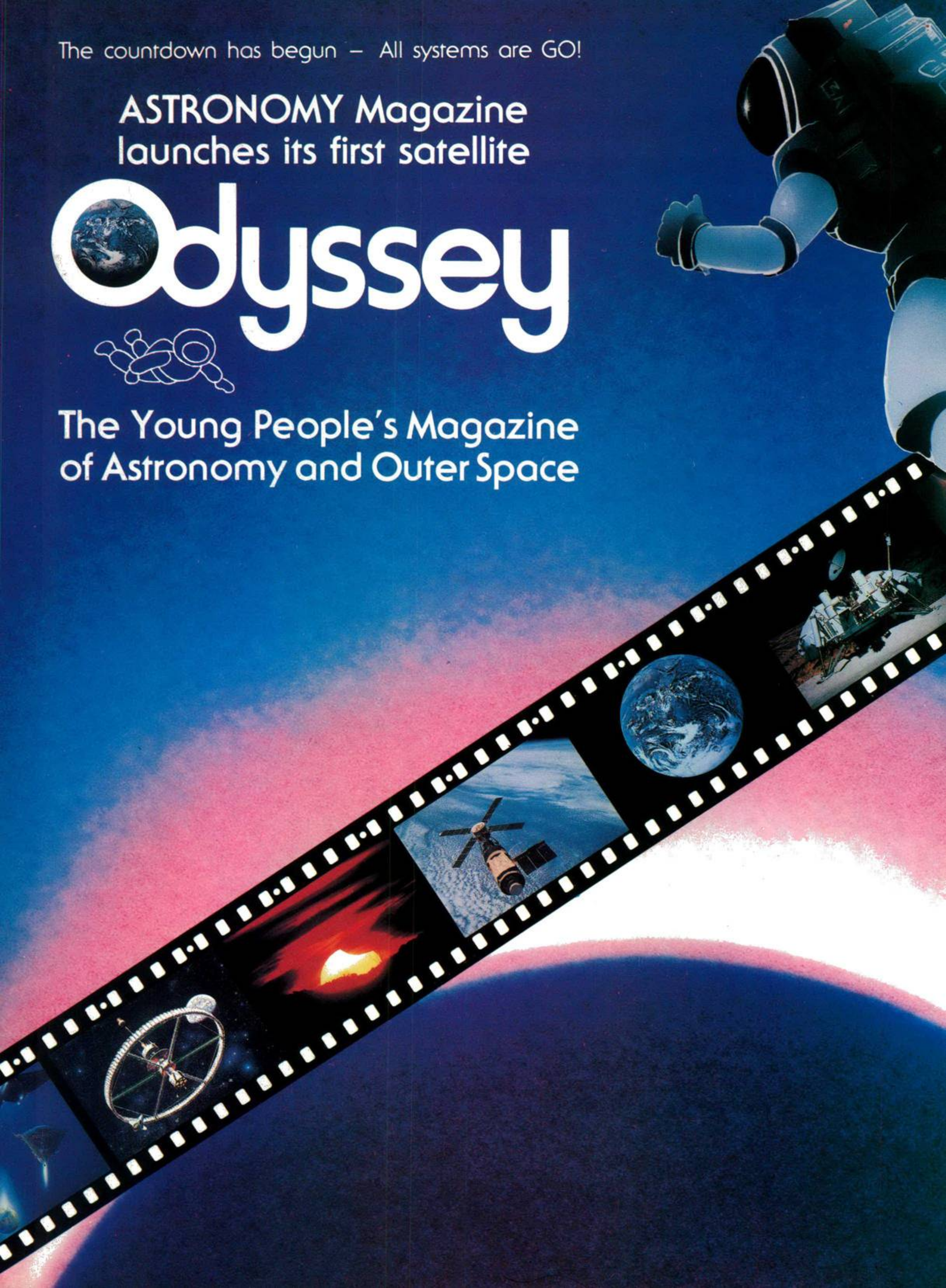
Other Uses for the "Eye in the Sky"

There are many useful applications of meteorological satellite imagery and data that are not obvious. A few hundred miles off the east coast of Florida in the extreme western Atlantic Ocean lie the Bahama Islands. Three of these islands, Andros, Grand Bahama and Great Abaco, have large reefs adjacent to them. West of Andros is the Great Bahama Bank; north of Grand Bahama and Great Abaco is the Little Bahama Bank. These are shallow coral reefs with an average depth of one to three fathoms. While past space vehicles (manned and unmanned) provided spectacular views of the Bahamian Banks, the newer meteorological satellites' radiometers can measure surface water temperatures with amazing accuracy. This advancement should have a tremendous impact on the sciences of meteorology, oceanography and marine biology.

So the next time you watch the television weather forecast, or wonder what tomorrow's weather holds, remember that we're watching it more closely than ever before. Your flight across an ocean may be safer too — indeed you wouldn't even know you flew around a big ITCZ disturbance!

Proper displayed, prepared, presented and disseminated, high and very high resolution visual and infrared photos from the DoD and NOAA meteorological satellites are "worth a thousand words". And weather analysts — worldwide — agree "the big eye in the sky doesn't lie".

Henry W. Brandli is a well-known professional image analyst and expert on operational satellite meteorology. He has published many articles in professional and technical journals, co-authored a chapter in the prestigious **Manual of Remote Sensing** *(published by the American Society of Photogrammetry), and has written his own book,* **Satellite Meteorology**. *Brandli, who retired from the Air Force in 1976 with multiple sclerosis, says: "Ironically, these last five years have been the most productive...."*



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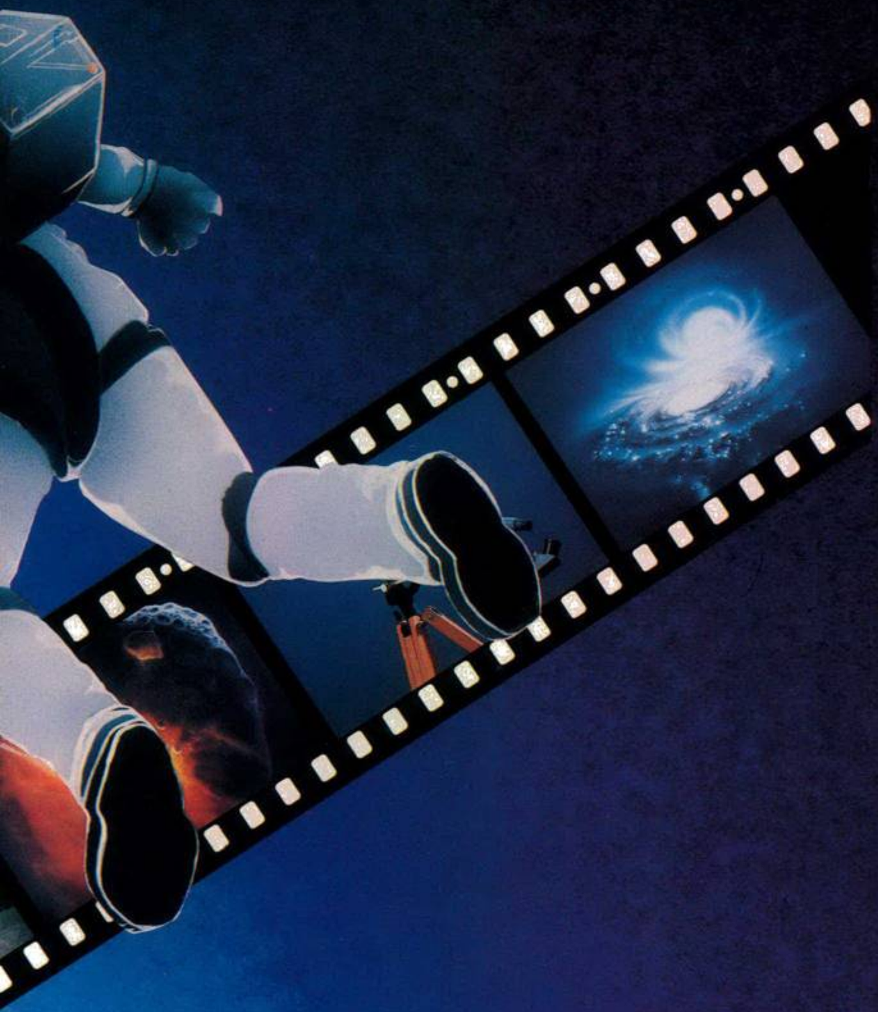

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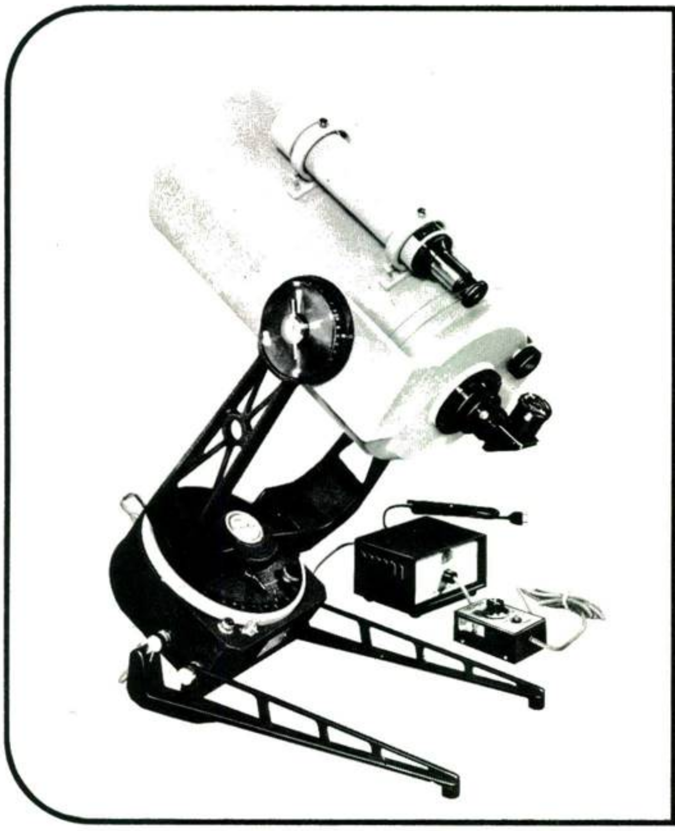

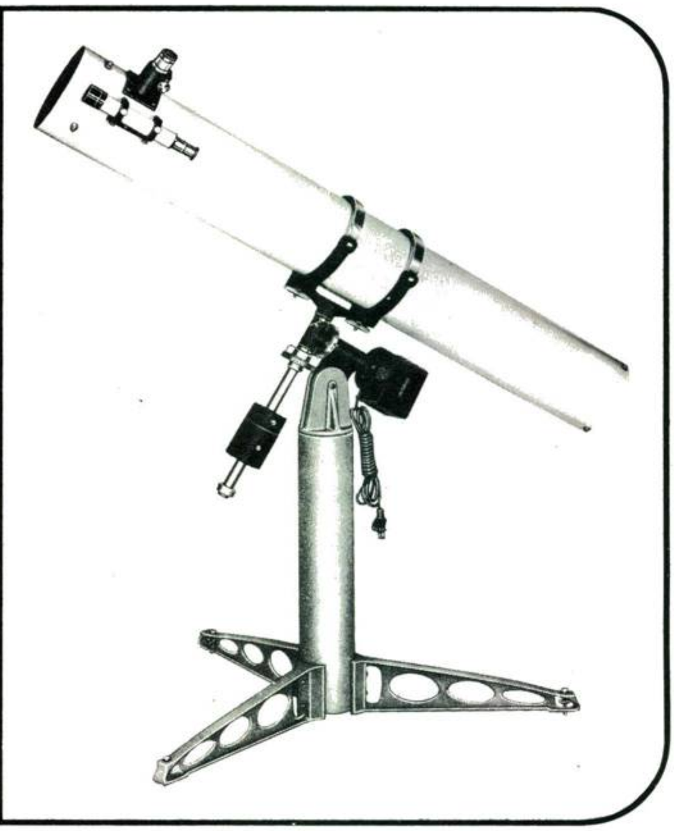

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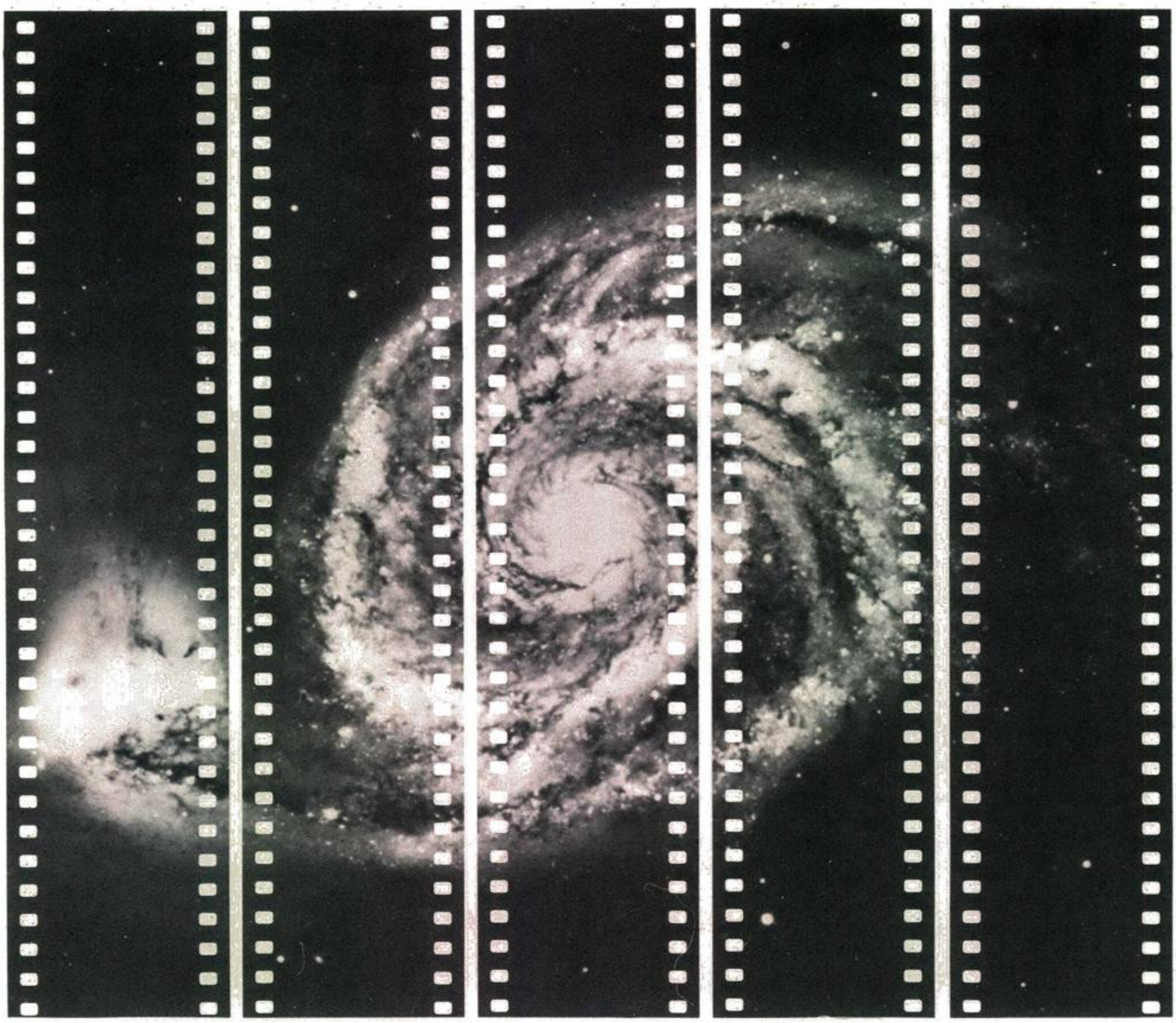

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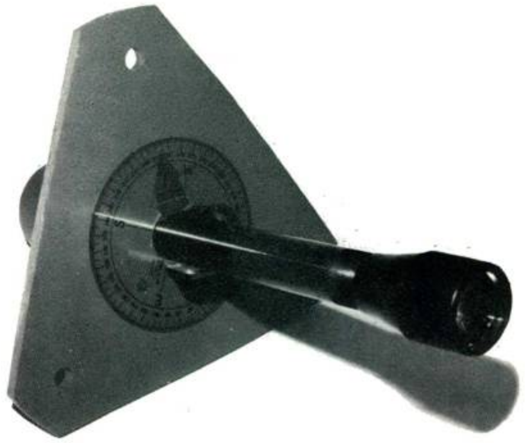

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Magnification........	7x	7x	11x
Objective Diameter...........	35mm	50mm	80mm
Angular Field........	11°	7.5°	4.5°
Linear Field (at 1000 yds.)..	576 ft.	393 ft.	235 ft.
Near Focus (approx.)..........	13 ft.	19 ft.	30 ft.
Interpupillary Range...............	52-78mm	52-78mm	52-75mm
Exit Pupil.............	5.0mm	7.1mm	7.3mm
Relative Brightness........	25.0	51.0	52.9
Twilight Factor.....	15.7	18.7	29.7
Relative Light Efficiency..........	41.3	84.2	79.4
Height..................	5¼"	7"	11¾"
Weight..................	2.2 lbs.	2.6 lbs.	5.0 lbs.

caps, carrying case and straps are included.

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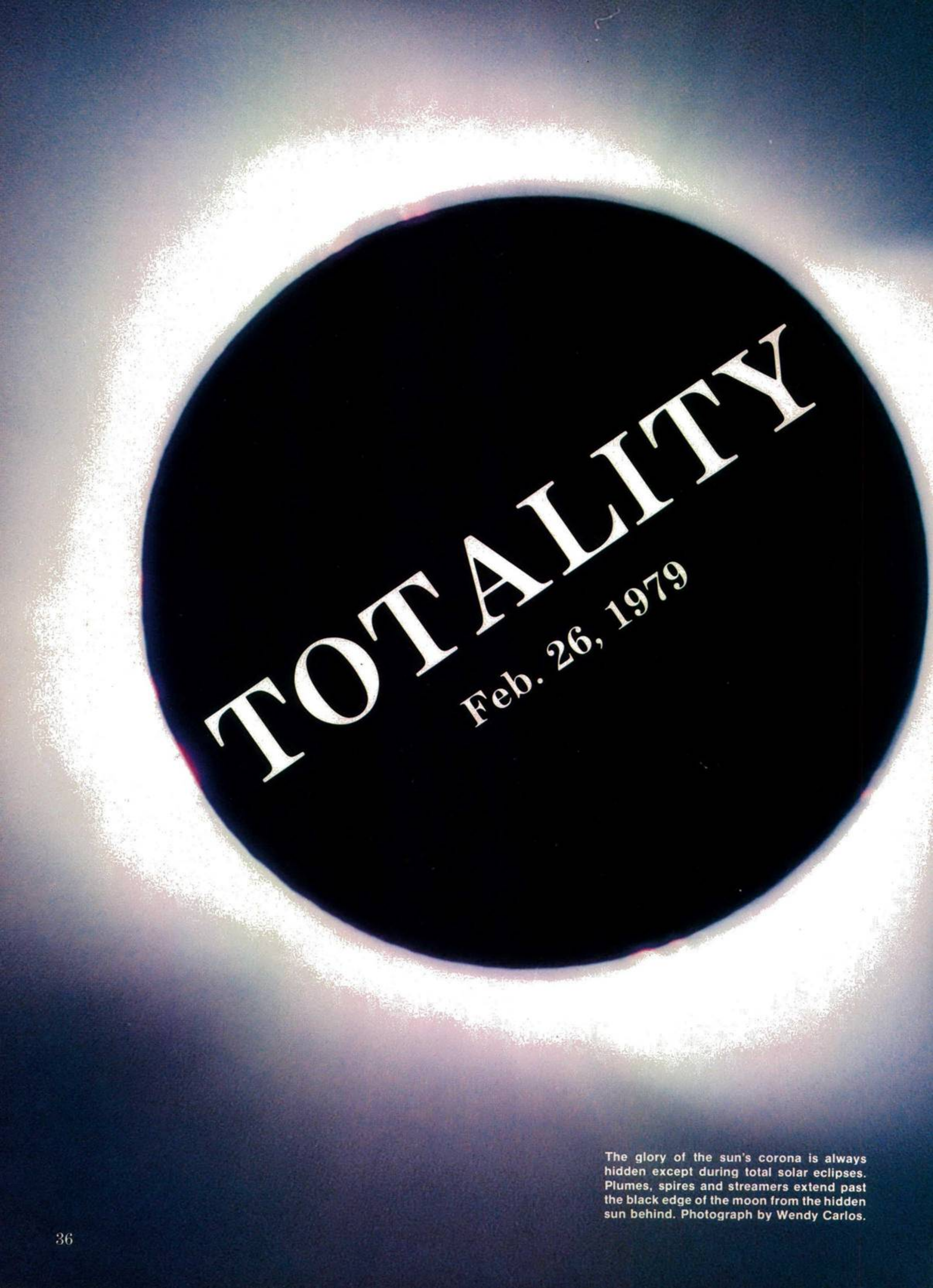


TOTALITY

Feb. 26, 1979

The glory of the sun's corona is always hidden except during total solar eclipses. Plumes, spires and streamers extend past the black edge of the moon from the hidden sun behind. Photograph by Wendy Carlos.

by
Richard A. Keen

Why travel halfway across a continent or farther to see a solar eclipse? After all, the cause of the event is simple enough — merely the passage of the moon in front of the sun. With such commonplace characters, how could the show ever live up to its advance billing? Would the experience be worth the trip?

Indeed, the first sighting of the slight notch on the sun's right hand side is not likely to cause much of a stir, except to reassure those present that they didn't make some horrendous mistake by going to the wrong place on the wrong day! The partial phases progress slowly, the growing bite out of the sun of interest to telescopic observers and warranting occasional checks by naked eye viewers with suitable filters. When the sun is about half covered, the first subtle impressions that something strange is going on begin to be felt. Darkness deepens as totality approaches; with 10 minutes to go, the effect is no longer subtle at all. From horizon to horizon, the sky above and the ground below have taken on the gloom of a premature dusk. Birds become agitated; so do photographers, fearful that reliable equipment will fail as the crucial moment approaches! Even nonphotographers become uneasy, as the visibly increasing darkness impresses on them that an event of enormous magnitude is about to happen, and they are totally powerless to slow or stop it.

Strangely, events then seem to speed up. The sun has thinned to the narrowest of crescents, and its remaining light feebly bathes the landscape with a fading reddish cast. The moon's shadow may be seen as a dark wall rising into the southwestern sky. Some observers may see the spectacle of this 80 mile wide cylinder of darkness descending from above. Shadow bands — alternating zones of light and dark about six inches apart — are seen rippling across surfaces such as walls and snow covered ground.

There's so much to see during the final seconds that you'll find yourself looking wildly in all directions — at the shadow bands on the ground, to the approaching shadow in the west, at the countryside slipping quickly into darkness, and above all, to that shrinking sliver of light which is all that's left of the sun.

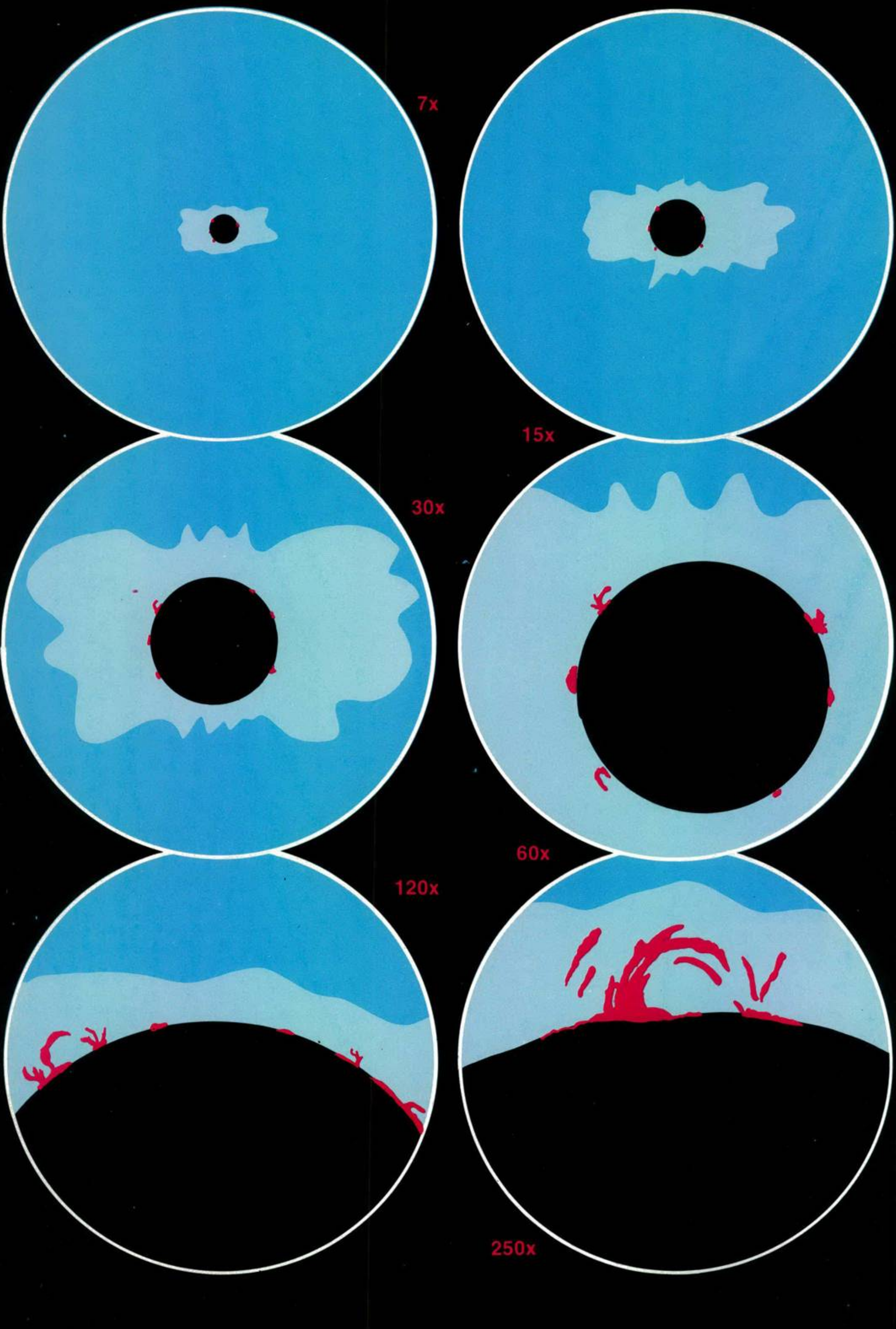
At this moment, the simple truth of this whole event bursts on you: The sun is going out! You know full well that this simple passage of the moon in front of the sun was predicted a century or more ago, and that it will be over in a couple of minutes. Yet there's something distinctly unsettling about seeing the sun blotted out from the sky! Mountains on the moon's advancing edge break that final sliver into beads of light, blinking them out one by one. Time seems to stop as the last bead resists extinction — but then it, too, is gone.

The eclipse is now total. Your eyes, not yet adjusted to the sudden onset of night, can see very little at first. Within seconds, however, your adjustment begins and the cold, steel blue of the sky and clouds becomes visible, its brightness reminiscent of twilight an hour after sunset. Along the horizon the atmosphere outside the shadow is a yellow-orange color against which mountains, clouds, trees and people are seen silhouetted. Overhead the bright stars of the summer triangle and a few planets shine forth. On Earth, living creatures (humans, too!) that were so excited minutes before now are still. The air cools noticeably; frost and mist may be forming in places. Even the wind may calm, adding to the eerie silence of the moment. The scene is strange enough, but peripheral to the main attraction, the ring of pearly light — the corona, the outer atmosphere of the sun. Its delicate streamers radiate outward until they fade against the indigo sky; at its center is the blank disk of the moon, a circle of blackness so solid it could be a hole punched in the sky, revealing a void beyond. Around the very edge of the moon several pink or orange spots of light may be visible; these are the solar prominences.

While taking in the beauty of the corona, you may not notice the ruddy glow of the returning daylight as it hurries in from the southwest. Your eyes were just getting used to the night; suddenly a blinding flash on the moon's right edge announces the end of the shortest two minutes of your life. Other beads of light join the display, merging into a growing crescent whose light obliterates the corona. Once again, shadow bands dance across the ground, and the moon's shadow may be glimpsed fleeing to the northeast until it vanishes on the horizon.

Daylight has returned. The show is over. You have certainly been overwhelmed, but you might not know just why. Perhaps it was the total immersion in a dynamic play of light and color, highlighted by the intricate artwork of the corona. Some people might see it as a graphic demonstration of the forces of nature, during which the immense size and relentless motions of celestial bodies are brought down to Earth. The mathematically inclined may marvel at the remarkable circumstances of geometry which make a total eclipse, and feel lucky to be at one of those rare points in space and time. Others will never forget their feeling of helplessness as the sun was reduced to a waning crescent, a powerful reminder of our dependence on that star.

Why travel halfway across a continent to see a solar eclipse? If one of the above reasons doesn't suit you, go anyhow. When you return you will have found enough reasons to change the question to, "When's the next eclipse?"


7x
15x
30x
60x
120x
250x

How to Watch an Eclipse

by
Robert Burnham

Many people will tell you how to photograph an eclipse. But how often does anyone tell you *what to see?* Without slighting photography in the least, we'd like to suggest how to observe the eclipse visually and what to look for if you do.

Apart from watching with the naked eye, there are a great many different types of binoculars and telescopes you can use, all having different features. Within broad limits, we'll consider them all equal, and describe what you'll see with various powers of magnification.

Viewing an eclipse with your eyes only (see box at right) shows a wonderful, and perhaps slightly frightening, sight. You are very aware of the event as it affects the sky and your surroundings. In effect, you are *involved* in the eclipse.

The sequence of events that occurs as the moon blots out the sun raises atavistic fears in all of us. Such fears go back thousands of years, explaining, perhaps, why an eclipse was an event superstitiously dreaded. Scientific knowledge has gone far toward erasing these primitive reactions, but not wholly. You may stand there knowing full well what's going on, but you still shiver a little as the dark shadow of the moon comes over. You've got the best of both ways in a sense: You know, but your knowledge hasn't destroyed your sense of awe.

What you see depends on what you have! This diagram shows the fields of view using various magnifications. The top row gives the view in binoculars, the middle shows that of a rich field scope, and the bottom moves you in close, using moderate powers on a conventional telescope. Diagram by Richard Berry.

Warning!

Solar eclipses are lovely to look at, but you can severely injure or blind yourself permanently during the partial phases if you don't follow these precautions:

NEVER, NEVER look at the bright photosphere of the sun, either with the naked eye or any optical instrument! Until the eclipse is *total* (that is, *all* of the sun is covered by the moon), you *must* use an optical projection system that throws the sun's image safely onto a piece of paper. Tripod mounted binoculars or the pinhole projector described on page 55 work well, but don't look THROUGH them — **project the image!**

When the partial phases are over and the corona bursts into sight, your eyes will still be dazzled; you won't see its full extent. Over the next few seconds, you'll begin to see more. At the risk of missing the final dramatic moments before totality, you might want to cover your eyes to help them adapt to the darkness. Full dark adaption takes many minutes (longer, in fact, than the eclipse lasts), but if you can start the process, you'll be able to see a bit more when the sun blinks out.

Looking up, there'll be a black spot in the dark, dark sky surrounded by a soft pearly blue light, about as luminous as the full moon. This is the sun's outer atmosphere, the *corona*. You'll probably notice that the corona's ring around the disk is somewhat uneven. Two lobes of light will likely extend out from the sun opposite each other. On the edge of the disk between them you may see some short spiky rays. The lobes come from the sun's equatorial region; the spikes stick out from the poles.

GAZER'S GAZETTE *continued on page 42*

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Quality Components and Accessories: Standard equipment on all 6" and 8" Meade reflectors — 6 x 30mm achromatic viewfinder with crosshair eyepiece; precision #67 rack and pinion focuser accepting 1¼" O.D. eyepieces; gleaming white Fiberlite tube, fully rotatable, with polished metal end rings; 4-vane spider; and 2 achromatic coated Kellner eyepieces; 9mm (135X) and 25mm (49X).

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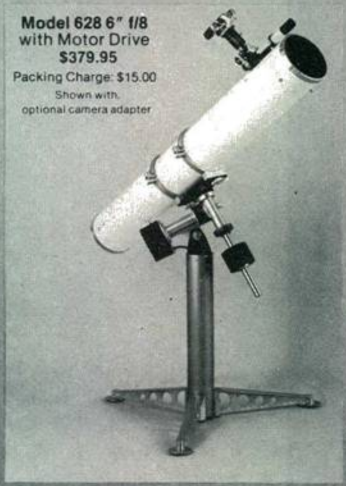

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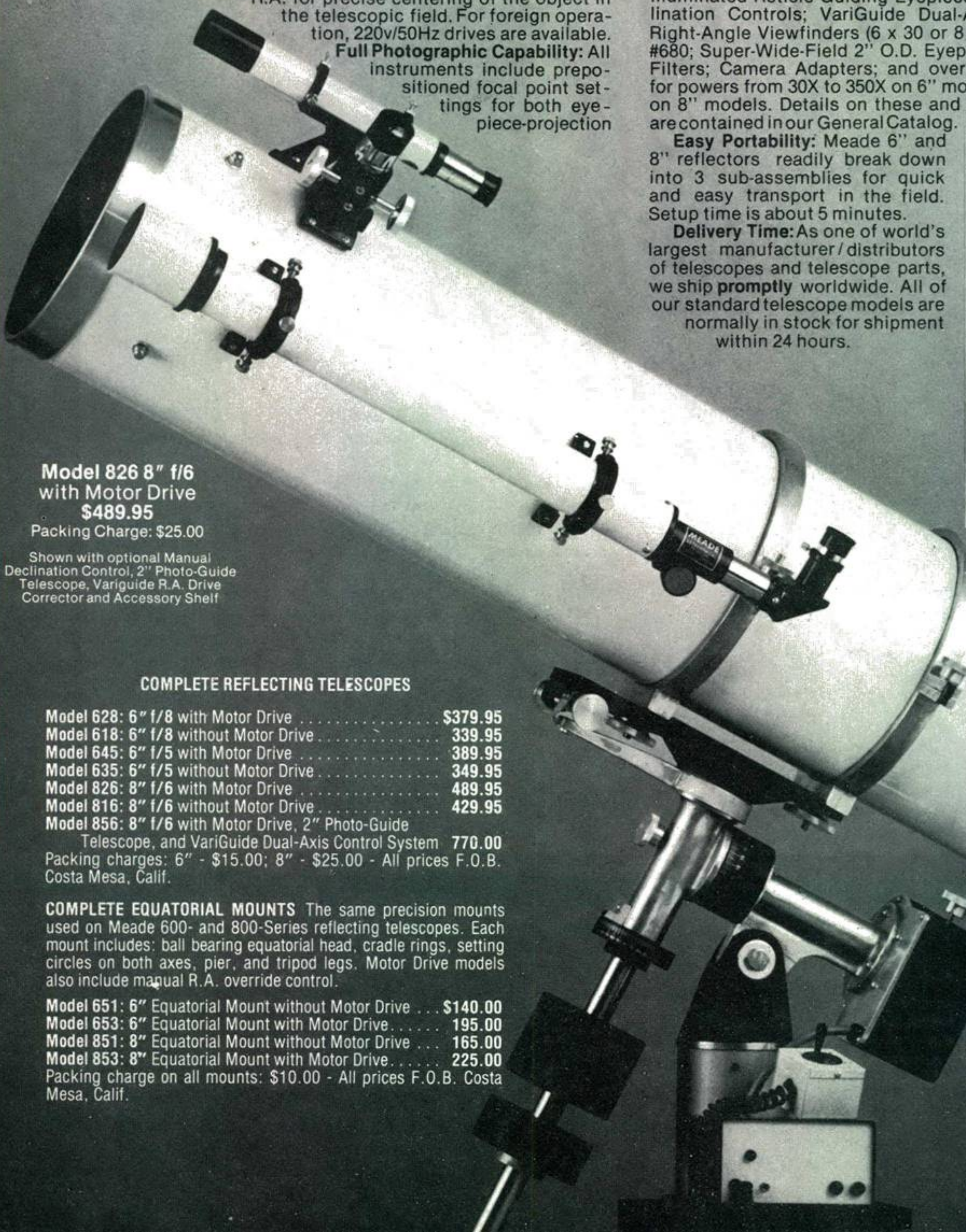
with Motor Drive
$379.95
Packing Charge: $15.00
Shown with optional camera adapter



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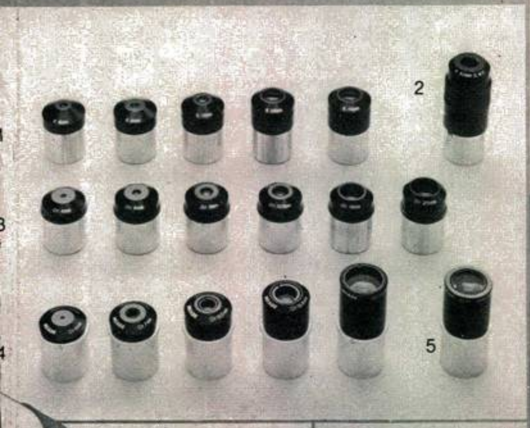

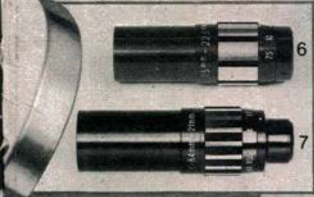

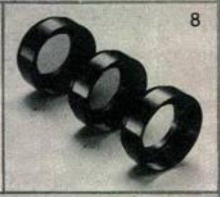

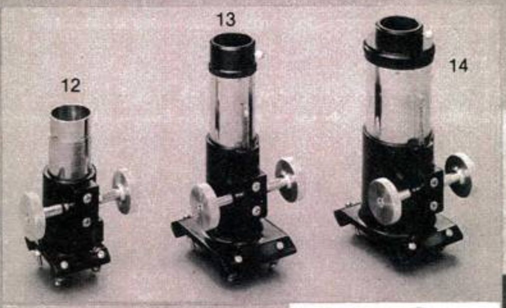

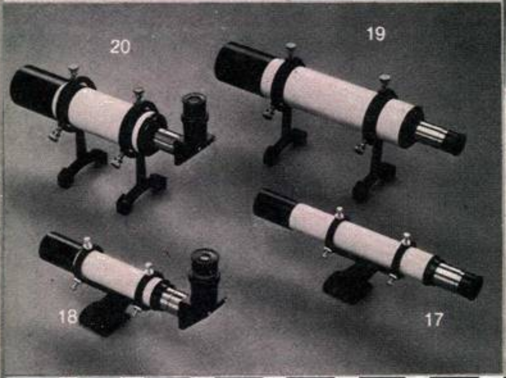

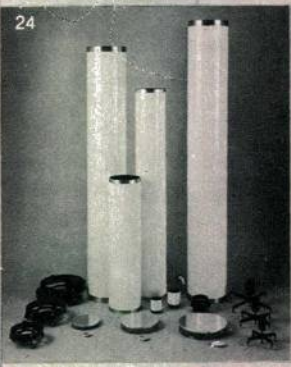

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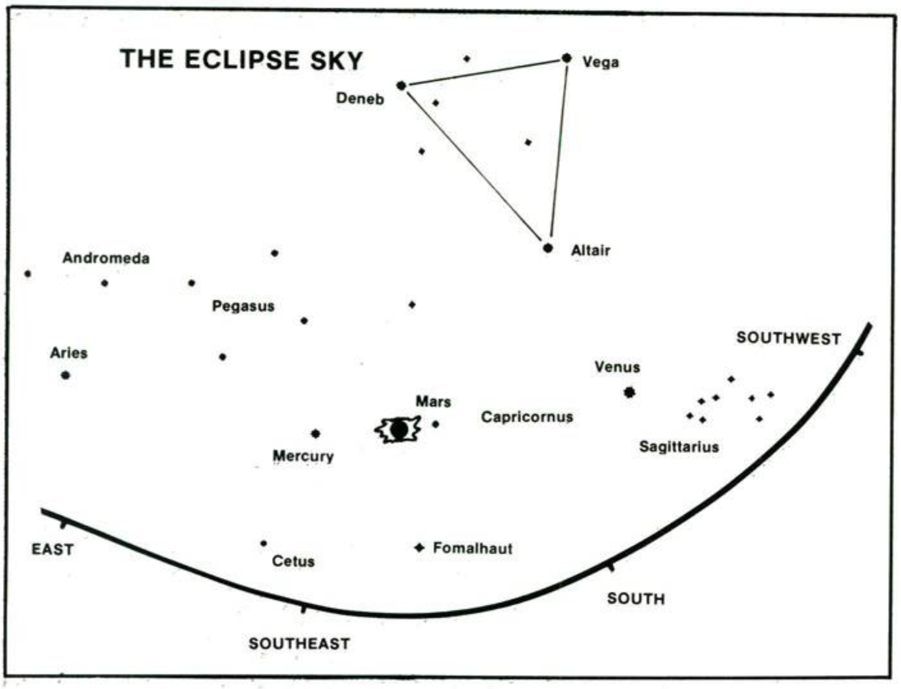
GAZER'S GAZETTE *continued from page 39*



In schematic form, this is what you'll see during the eclipse if you are stationed about the middle of the eclipse track in southern Manitoba. Flanking the sun are Mercury (left) and Mars (right). Venus is in the south, below the summer triangle. Just above the horizon below the sun lies Fomalhaut, the first magnitude star of Piscis Australis. Farther away are the Great Square of Pegasus and, just setting, the teapot of Sagittarius.

Looking closely at the black edge of the disk, you might notice little points of bright pink light. Called *prominences*, these are plumes of the sun's surface material thrown up by magnetic disturbances.

See if you can note irregularity or streaming in the lobes, and then estimate how far out from the disk they extend. A quick sketch now will help you remember later!

Gleaming in the sky around the sun will be several planets and bright stars. At this time of year, the sun lies in the center of the constellation Aquarius. To the northwest you'll see the stars of the summer triangle — Vega, Altair and Deneb — a very odd sight in February!

Fifteen degrees to the left (east) of the sun is Mercury, shining at magnitude -1.0. Glowing redly seven degrees to the right (west) of the sun lies +1.4 magnitude Mars. Forty-five degrees to the right, under the summer triangle, you'll spot Venus, unmistakable at magnitude -3.7. South of the sun you may glimpse Fomalhaut, the first magnitude star in Piscis Australis.

Depending on your location (which governs how high the sun will be during the eclipse), you might miss Mercury. Those who are observing at the western end of the eclipse track will find the sun very low. For them, Mercury simply won't have risen yet. Also, the planets' positions above your horizon will differ from place to place. For example, the west will see Venus east of the meridian; Montanans will see it on the meridian, and Manitobans will see it past the meridian and down toward the southwest.

If you are going to use optical equipment, you'll see different sights, depending on just what you have. The diagram on page 38 shows what a given magnification will reveal.

Binoculars have a power range from about 5x at the low end to 20x at the high. The most common ones are 7x. A seven power field is about seven degrees across; since the sun covers 1/2 degree, you'll see the disk and corona centered with a wide ring of dark sky all around. The lobes at the equator are bright next to the disk, and trail off into the sky farther out. The lobes show streamers, some of which will catch your eye better than others. Small plumes shoot out perpendicularly from the disk in polar areas. Close in are little red prominences — though "little" here is relative! In reality, they are far larger than Earth, and some have shot out hundreds of thousands of miles above the sun's surface!

Try to ascertain the shape of the corona, using the solar diameter as a unit of measurement. You may even get the sun and Mars in the same field of view, but Mercury will definitely lie outside it.

You'll move in closer to the sun with 15 to 20 power. The field of view is some 36 degrees at this power, and some people will find this a pleasant magnification. The sun and corona will fill the center of the frame, and details that would need closer scrutiny with seven power will now be clear. If you use binoculars, be sure they're mounted on a tripod, though! It's almost impossible to hold 15x binoculars steady enough to get a good view. Wide field telescopes and small RFTs will serve admirably at this power.

There may be a large prominence visible, so perhaps you can glimpse some of its shape. The lobes of the corona are often markedly asymmetrical, sometimes favoring one side of the sun or another. This eclipse happens at neither sunspot minimum nor maximum, so the exact shape isn't predictable. At times of minimum, lobes and polar plumes stand out; near maximum, the distribution is basically even all around the disk.

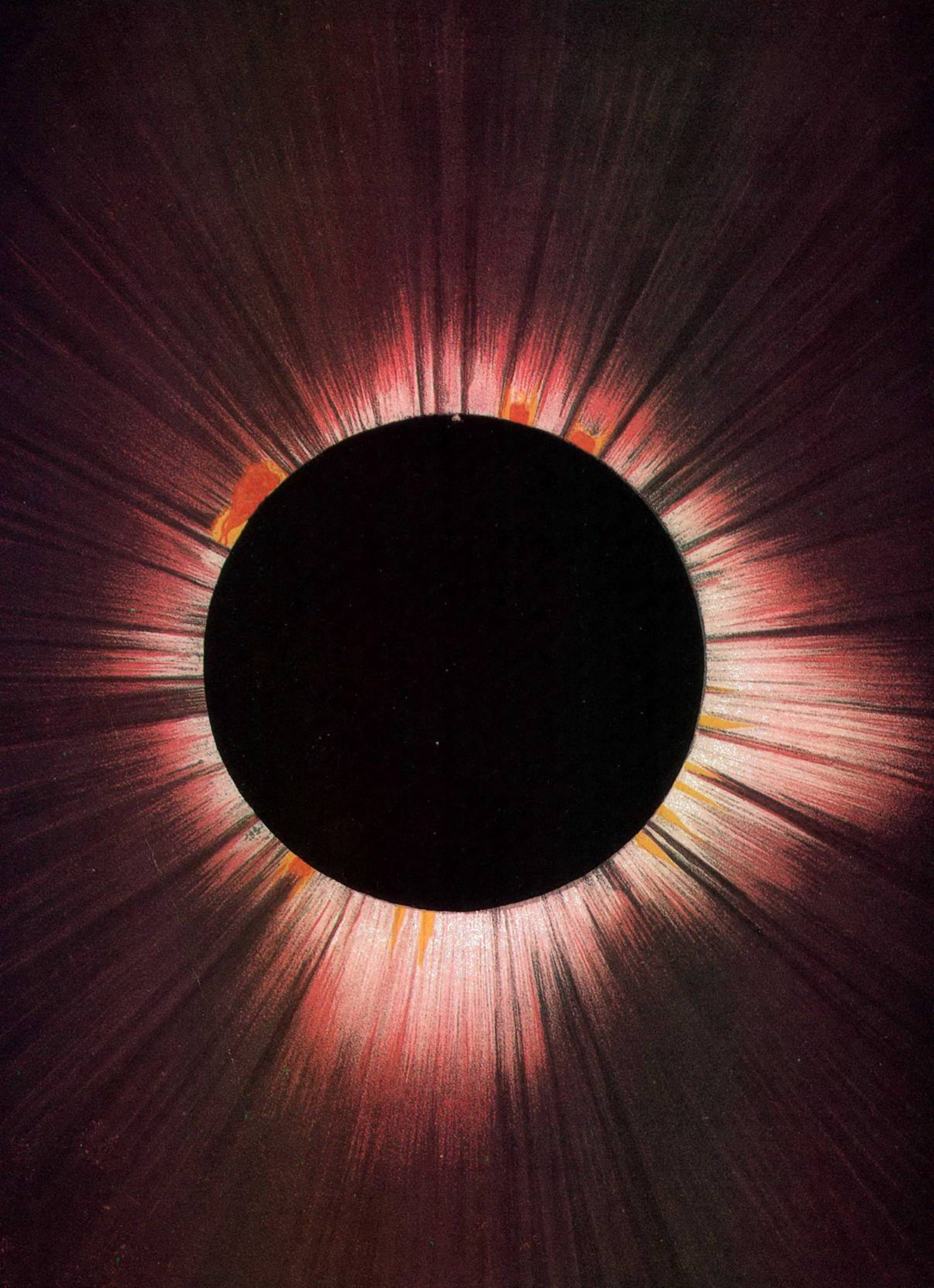
Moving to 30x probably means using a telescope, since few binoculars have a power that high. And this magnification gives such a *glorious* view! The field is 1-1/2 degrees wide, so the sun and corona comfortably fill the frame. The corona looks much like sunlight streaming past a high dense cloud, but the streamers are not an optical effect; they're real. Polar plumes will have detailed structure, and unless you're unlucky, the prominences should be high enough to show some details as well.

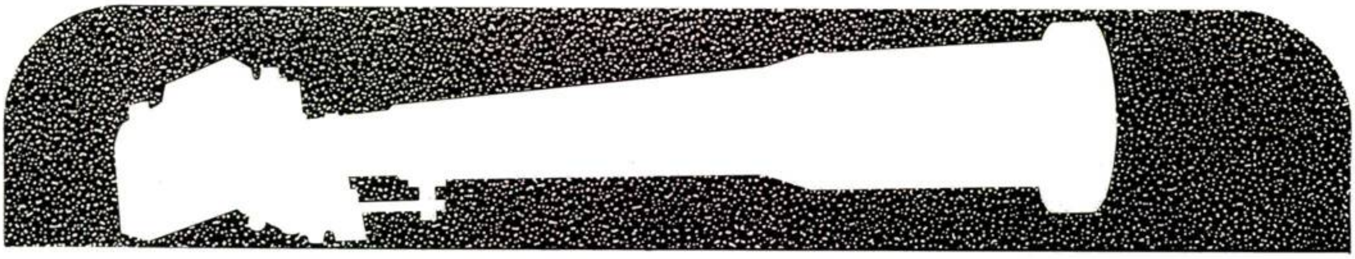
When you look at 60x, you begin to lose some of the outer corona — the field is only 3/4 degree wide! To see the full range of the corona from the disk outward, you'll have to aim the scope off from the center of the disk. The corona's inner parts will have structure clearly visible and the prominences will be intricate.

You may see different types of prominences: They exist as *eruptive* and *quiescent* ones, but the only difference you'll see between them during the eclipse is form. The eruptive ones, resembling tongues of flame and moving with great velocity, are so huge that many minutes'

GAZER'S GAZETTE *continued on page 55*

This old lithograph was prepared to show what the Aug. 7, 1869 total eclipse looked like to an observer with a four inch telescope. Most striking are the rays in the corona, which are often hidden in photographic renderings, but stand out clearly to the eye. Also shown are the prominences which appeared like "anthracite coals in a fire grate". Besides the orange color of the prominences themselves, some appeared to be flecked with red. Lithograph from observations of W. S. Gilman Jr. at St. Paul Junction, Iowa, and printed in the USNO report on the event.





PHOTOGRAPHY IN ASTRONOMY

Film the Eclipse!

by
Richard Berry

Almost everybody who goes to an eclipse takes a camera, and if clouds don't make it completely hopeless, everybody with a camera takes a picture. And, wonderfully enough, almost everybody who tries *gets* a picture!

EXPOSURE GUIDE for the Solar Eclipse

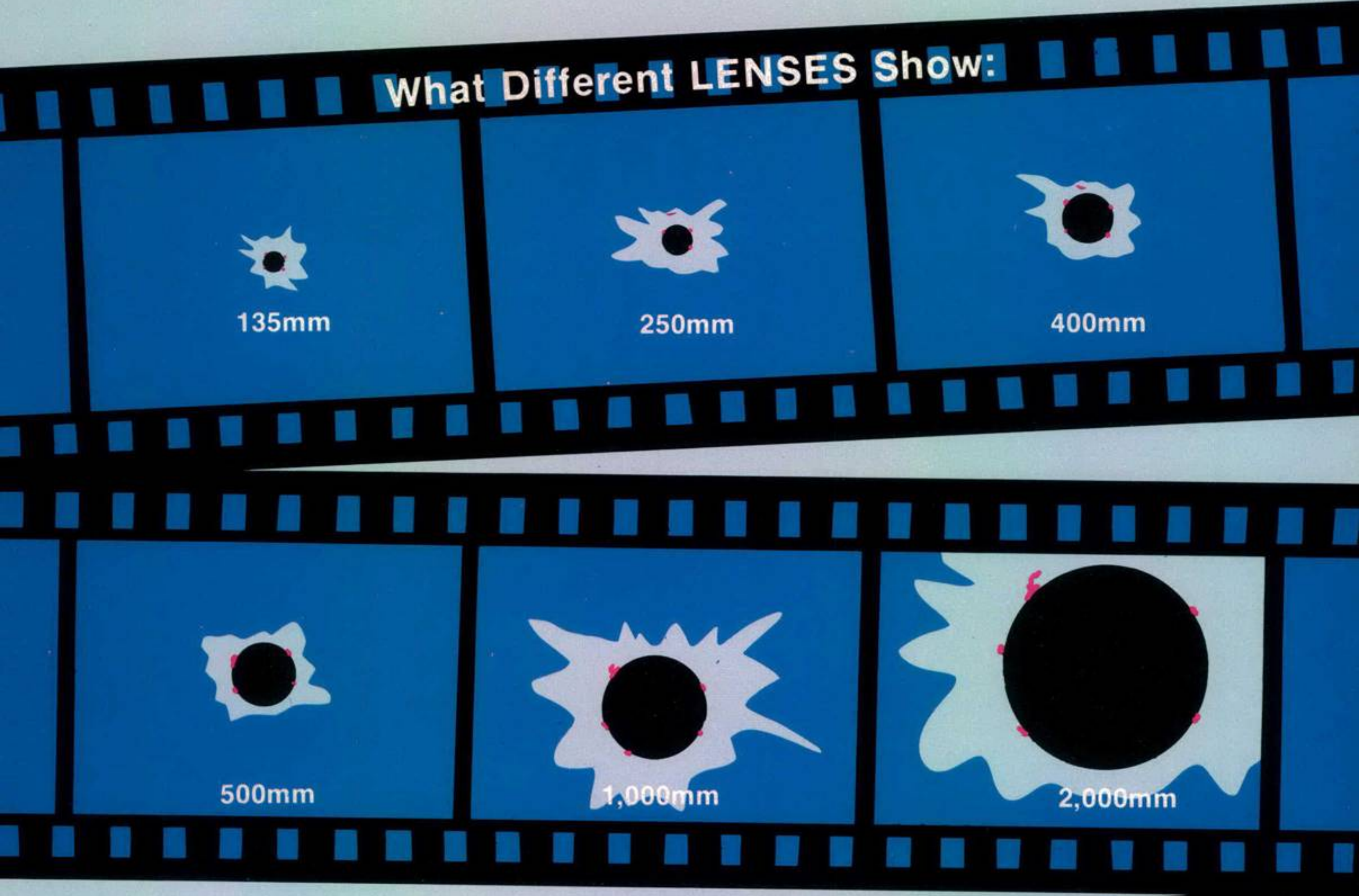
Film Speed	**f/ratio of optical system**					
25	1.4	2	2.8	4	5.6	8
50	2	2.8	4	5.6	8	11
100	2.8	4	5.6	8	11	16
200	4	5.6	8	11	16	22
400	5.6	8	11	16	22	32
Feature of Interest						
Prominences	—	1/1000	1/500	1/250	1/125	1/60
Inner Corona	1/1000	1/500	1/250	1/125	1/60	1/30
Middle Corona	1/60	1/30	1/15	1/8	1/4	1/2
Outer Corona	1/8	1/4	1/2	1	2	4
Extreme Corona	1	2	4	8	16	32

exposure in seconds

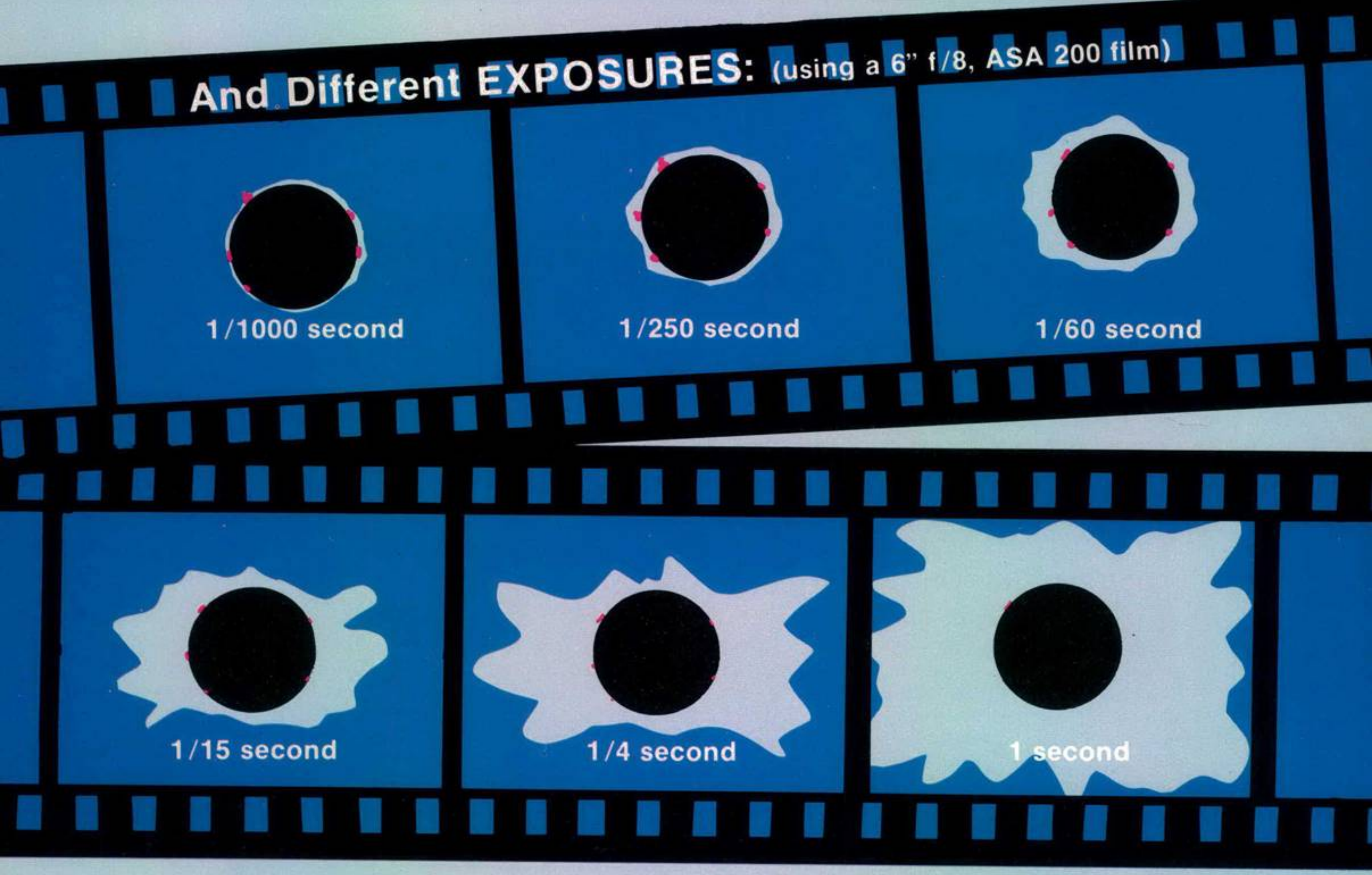
Eclipses are very forgiving: You can use almost any lens, camera or exposure, and come away with a decent shot of totality. Why? Because the eclipsed sun shows a huge variation in brightness. The brightest parts of the inner corona are as bright as a sunny day at the beach, while the faintest outer edges of the corona are tens of thousands of times fainter. So it's practically impossible to under- or overexpose: The film will register some part of the great natural spectacle before the camera almost without thought on the photographer's part.

However, such an approach is uncontrolled — you're at the mercy of your equipment. Why not take the

What Different LENSES Show:


135mm
250mm
400mm
500mm
1,000mm
2,000mm

And Different EXPOSURES: (using a 6" f/8, ASA 200 film)


1/1000 second
1/250 second
1/60 second
1/15 second
1/4 second
1 second

What To Look For If It's Cloudy

by

Richard A. Keen

Nobody wants to see clouds at a solar eclipse, but for this one they are a likely possibility — so be prepared to make the best of overcast skies!

Of course, the main attraction of an eclipse, the corona, will be invisible if the weather's bad. But if the clouds are *just* right, they can actually improve the view of the partial phases by acting like a filter. The vanishing solar crescent makes a dramatic sight through a thin layer of clouds, though even the most tolerant observer will be disappointed when the corona fails to flash into view. The burst of sunlight at the end of totality is quite spectacular if seen through a not-too-dense overcast, since it looks like a gigantic flare being set off.

The phenomenon gaining most from cloudy skies, though, is the overhead passage of the lunar shadow. The edge of the shadow will be surprisingly sharp, especially if it's cast on a middle or high level cloud deck. Sweeping from southwest to northeast at nearly 2,000 m.p.h., it's an awesome and unforgettable sight. You won't see the shadow until less than a minute before totality, but during the next 60 seconds you'll probably want to duck as its enormous dark presence engulfs the sky above you.

In contrast to the deep blue of the sky during totality, you'll see a yellow-orange glow along the horizon. This is the cloud layer outside the shadow. (To the southeast — in the direction of the sun — the shadow may appear as an inverted cone extending to the horizon, moving from right to left.) The motion of the shadow can be sensed in all directions; be sure to notice the continuously changing colors in the sky. To the southwest an onrushing salmon colored dawn will signal the end of totality, and you may be able to see the shadow to the northeast for another minute as it retreats. The shadow won't be very pronounced if the weather is low overcast or foggy, but such soupy conditions should intensify the darkness of the eclipse, and enhance the already powerful effect of watching the entire visible world plunge into night.

Depending on the type and thickness of the clouds at the time of the eclipse, some of these phenomena may be visible, and some may not. But no matter what the weather is, the eclipse will happen, and there will be many strange and beautiful sights to behold!

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situation in hand and decide now what you'd like to photograph? You'll need to decide how big you want the image, what you want to see in it, and how you'll want to display it.

You have control over three aspects: the image size (by choice of lens or telescope), what parts of the eclipse to get (by film speed and exposure time), and how to display it (by choice of film type). The diagram on page 45 shows you the size of the solar image for a variety of focal lengths. With normal lenses on your camera, the image is small; with telephoto lenses it's bigger, and with telescopes it's larger still. Remember, an image that's too big can spill over and out of the frame, while an image that's too small won't show much detail.

Next, look at the other diagram . Here the focal length is the same in all cases, but the exposure varies over a wide range. The shortest exposures show just the prominences and innermost corona, while the longest exposures show the corona merging into the scattered light of the background sky. Obviously, you'll want to make more than one exposure to record the full range of beauty of the solar eclipse!

Next, consider carefully just how you'd like to see the final image. What type of film will give you what you're looking for? Black and white film will yield fine detailed negatives for big black and white prints. Color negative films will give you standard pocket sized enlargements. In addition, you can have big color or black and white blowups made from the best negatives, and you can have color slides made from them as well. Color slide film offers the convenience and dramatic effect of projection, and you can have color prints made from them. The choice really depends on your personal taste to a large degree. From the standpoint of total flexibility and quality, color negatives are probably the best all-around bet, followed closely by color slide films.

Finally, temper all your glorious imaginings with a realistic guess about the weather (cold!) and the operability of camera and telescopic equipment under those conditions (difficult!); then try to come up with a combintion you're sure you can get to work.

What's the best bet? It's probably a long focal length telephoto lens (in the 400mm to 1,000mm range), and a range of shutter speeds from a few seconds to 1/125 second on a medium speed color negative film. Almost as foolproof would be a 35mm camera solidly mounted at the Newtonian focus of an RFT (such as a six inch f/4), or a camera mounted on a five or six inch Schmidt Cassegrain using the same combination of film and shutter speeds. These systems will give you fields of view between six and two solar diameters — wide enough to show most of the corona while retaining acceptable resolution of prominences in the shortest exposures.

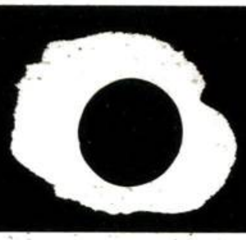
If you have a second camera (remember there won't be time to change lenses during the eclipse!), you may want to use a normal or wide-angle lens to record the dramatic semidarkness of the sky at totality and within a few minutes of second and third contact. Fisheye lenses can give dramatic sweeps of sky, horizon and clouds, especially if striking foreground objects can be included.

Remember, too, that the low altitude of this eclipse — less than 26 degrees everywhere — means that even a normal lens spans enough angle to include the horizon at the bottom of the frame! West Coast observers may, if the weather is good to them, find that even a telephoto lens can include foreground to good effect.

The exposure times for the eclipsed sun are not very critical: If you over- or underexpose, you'll simply show other features of the corona. Try a wide range of exposures using the values shown in the table on page 44 as rough starting points.

Finally, remember two important points: Don't go to the eclipse just to get pictures! Fiddling with equipment during those precious two minutes could rob you of seeing the full beauty of the event. Keep your equipment simple, reliable and modest. The other point is: Be prepared for cold weather. Keep your camera warm or winterize it. Remember that the battery in your camera (if it has one) could freeze up and stop working. Wind film v-e-r-y s-l-o-w-l-y to avoid static marks and torn sprocket holes. Film is very brittle in the cold, and sometimes snaps in two if it's suddenly flexed by winding quickly.

Editor's Note: We expect to see a huge influx of pictures from our readers after the eclipse. Please write "Eclipse Pictures" on the envelope so we can separate them from other correspondence. And please remember that we will need them for several months if we are to consider them for publication. Send us just a few of your very best photos, rather than everything you took. That way we can be fair to you, because it simply won't be possible to return pictures *immediately*.



ECLIPSE SPECIAL

by
Dan Koehler and Richard A. Keen

Sites and Weather

A total eclipse gives viewers an opportunity to enjoy nature's beauty and majesty at its finest. For centuries, people have watched eclipses and woven fanciful tales to explain the puzzling and frightening phenomena. Ancient civilizations saw monsters, dragons perhaps, "gobbling up" the sun while the brave heroes of mythology battled demons to insure the safety of Earth's blazing luminary.

Today, of course, we approach solar eclipses with a more secular and scientific attitude. Experiments conducted during total solar eclipses have taught us much about the nature and structure of the sun's outer atmosphere, the corona. Astronomers of all kinds flock to eclipse sites, armed with instruments, complicated or simple, to record the magnificent sight of the corona and collect further knowledge about our life-giving star.

On Monday, Feb. 26, 1979, Americans and Canadians will have their final opportunity of the 20th century to view a total solar eclipse within North America. Starting at the Pacific coast in Oregon and Washington, the moon will pass directly in front of the sun at approximately 8:12 a.m. (PST). The moon's shadow will then travel on an eastward, and later a northeastward, track across the states of Washington, Oregon, Idaho, Montana and North Dakota. At approximately 10:45 a.m. (CST), the shadow will leave the United States and proceed northeast into the Canadian provinces of Saskatchewan, Manitoba, Ontario and Quebec. The event will end in the interior of Greenland at sunset.

Maximum duration for the total phase of the eclipse will be 2 minutes 52 seconds, just east of Lake Winnipeg in Manitoba. Although the eclipse isn't a long one, the event is notable for its wide path of totality. The maximum path width for this eclipse is 195 miles, near Williston, N. D., just south of the U.S.-Canada border. Throughout the U.S. and Canada, the eclipse track will usually be 175 miles wide or more, thus including a large number of small towns and communities.

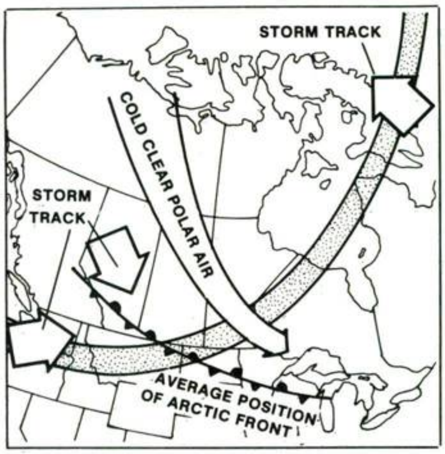
During a total solar eclipse, four separate and distinct events happen as the moon gradually covers and uncovers the sun. These events, known as *contacts*, can be timed with shortwave radio time signals. First contact begins as the moon makes its very first silhouetted appearance against the bright disk of the sun. The partial phases follow. Second contact occurs about one hour after first contact, when the moon completely hides the sun. Totality follows as the corona streams out in all its glory. Only a few minutes later, totality ends when the moon's eastward motion uncovers the western edge of the sun's disk, marking third contact. During the next hour, the moon reveals progressively more of the sun. At fourth contact the moon has completely uncovered the sun and the eclipse ends.

Observing Sites

Generally speaking, there are five areas within the U. S. and Canada having particularly favorable chances to view the February 1979 eclipse: the Columbia River Basin in Washington and Oregon; eastern Montana; northwestern North Dakota; southeastern Saskatchewan, and southern Manitoba. Each of these areas offers eclipse viewers something different: favorable weather prospects, adequate accommodations, beautiful scenery, interesting cultural activities, or just good observing sites. If you plan to visit these areas to watch the eclipse, you should thoroughly examine a site not only for its observing qualities, but also for the availability of accommodations. Not all the cities or towns listed here have hotels, motels or campsites. Check with travel guides or the like for a specific state or province for further information about accommodations; now is not too early to make your arrangements! The American Automobile Association and Canadian Automobile Association can help you with details.

Columbia River Basin

The Columbia River Basin forms most of the state line between Washington and Oregon. You'll find many beautiful observing sites on either side of the river. On eclipse day, the center line of totality will run very close to the Columbia River between Astoria, Ore. and Walla Walla, Wash. The best locations in Washington will be Goldendale, Umatilla, Yakima, Richland, Pasco and Walla Walla. Favorable sites on the Oregon side will be found along the Columbia River in



Above: The weather masses affecting eclipse observers are shown here schematically. Actual weather conditions will depend on the location of the arctic front at the time of the eclipse.

the area between Dalles and Pendleton. Several colleges and universities in Pendleton, and in Washington at Pullman, Walla Walla and Ellensburg, have offered outsiders their campuses as observing sites. The following individuals should be contacted for further information: Katherine Bracher, Associate Professor of Astronomy, Whitman College, Walla Walla, Wash. 99362; Robert C. Mitchell, Professor of Physics, Central Washington State College, Ellensburg, Wash. 98926; Thomas E. Lutz, Associate Professor of Astronomy, Washington State University, Pullman, Wash. 99164, and Ellsworth E. Mayor, Dean of Academic Planning and Research, Blue Mountain Community College, 2411 N.W. Carden, P.O. Box 100, Pendleton, Ore. 97801. For information about viewing plans at the Goldendale Observatory (a public facility), contact William F. Yantis, Director of the Goldendale Observatory, P.O. Box 555, Goldendale, Wash. 98620.

Many amateur and professional astronomers intend to observe the eclipse from Goldendale. The observatory is outside the city on high land, offering an extensive, unobstructed view. Second contact, or the beginning of toality, will occur in the Columbia River Basin about 8:15 a.m. (PST). The sun's low elevation at eclipse time could be a problem for observers at this site. First contact happens here shortly after sunrise, and the sun will be only 14 degrees high by second contact.

In addition to the college campuses listed here, Sherry Redinger of the Richland (Wash.) Chamber of Commerce has suggested several parks in the Richland-Kennewick-Pasco area that could make excellent observing sites. They include: *Columbia Park*, located on the Columbia River; *Fishhook Park*, 27 miles from Pasco on U.S. Highway 395; *Levey Park*, 14 miles from Pasco on the north bank of the Snake River; *Two Rivers Park*, five miles east of Kennewick on the Columbia River; *Horn Rapids Park*, 11 miles northwest of Richland and 10 miles northeast of Benton City, and *Howard Amon Park*, on the George Washington Way and Lee Boulevard in Richland.

Eastern Montana

As the eclipse shadow moves eastward, there should be a general improvement in the chances for clear skies. By 9:25 a.m. (MST), totality will have begun at Helena, Mont., located on the eastern slope of the continental divide. East of Helena the topography is increasingly flat and plainslike. Other possible sites in eastern Montana include Great Falls, Lewistown, Roundup, Jordon, Glasgow, Wolf Point, Glendive, Circle, Culbertson, Sidney and Froid. (Helena, Lewistown, Poplar and Froid are all conveniently located near the center line of totality.) Most of eastern Montana is open farming country and, given a clear morning, offers viewers spacious skies. The sun's elevation in eastern Montana will be 20 degrees at Helena, increasing to 24 degrees at Culbertson near the Montana-North Dakota state line.

The Astronomical League, an organization of more than 160 astronomical societies from all over the U. S., has chosen Helena as their observation site. Dean Robertson, principal of the Malta (Mont.) High School and coordinator of eclipse activities at Malta, has suggested that observers will have little trouble setting up anywhere along the eclipse path in Montana. For further information about Helena and other Montana sites contact Prof. Russell C. Maag, c/o Planetarium, Missouri Western State College, 4525 Downs Drive, St. Joseph, Mo. 64507. Maag is chairman of the Astronomical League's Eclipse Expedition Committee, and can provide observers with information about sites in the U.S. and Canada.

Northwestern North Dakota and Southeastern Saskatchewan

Improved chances of clear weather should make this area of the eclipse path more favorable to observers traveling from the eastern U.S. This region will also experience longer times of totality and a wider path than previously mentioned areas. North Dakota offers eclipse viewers flat, open country and crisp skies for unobstructed observation. Only two large cities are in the eclipse path — Minot and Williston, both south of the center line of totality. Totality at Williston begins at 10:35 a.m. (CST) with the sun 24 degrees high.

The northern limit line and center line of totality leave the U.S. and enter Canada in Saskatchewan. Two large cities, Weyburn and Estevan, will enjoy totality duration times of 2 minutes 18 seconds and 2 minutes 43 seconds respectively, with a sun elevation of nearly 24 degrees. Totality starts at both sites at 10:38 a.m. (CST). Southeastern Saskatchewan is quite flat and will offer eclipse watchers clear views of the event if skies are cloudless.

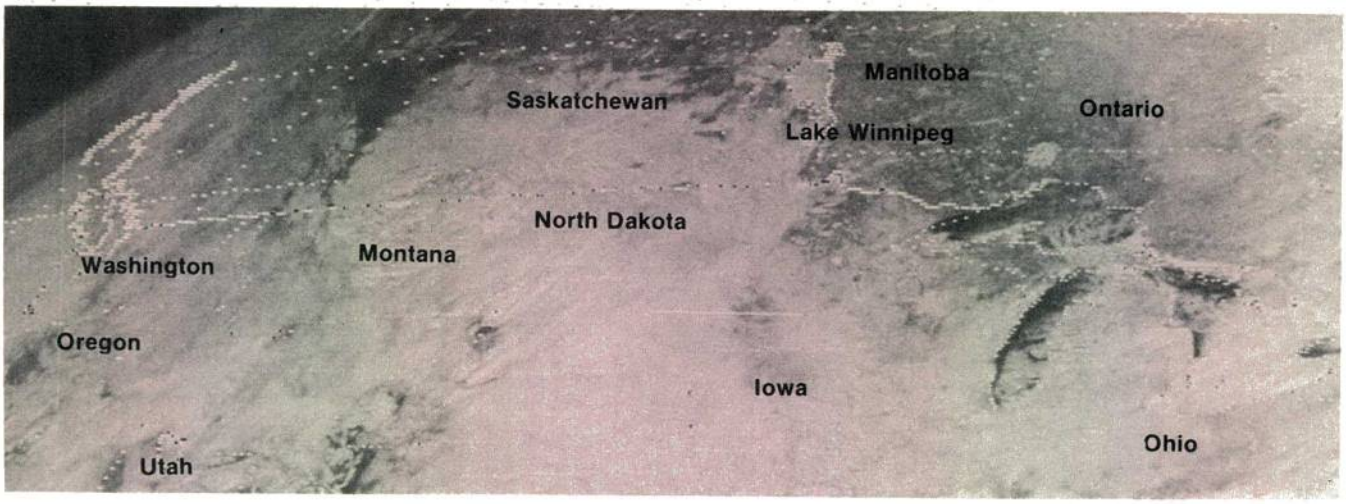
Southern Manitoba

Southern Manitoba will likely be the center of attraction for eclipse viewers in North America. The region has open farm country providing a limitless view on a clear day, good highways, plenty of accommodations, and the longest total eclipse duration times of any region in the eclipse path. Winnipeg, the largest metropolitan area to experience the total eclipse, is located almost halfway between the southern limit and center line of totality. This city of 572,000 inhabitants is easily accessible by car, plane or train. Eclipse viewers in Winnipeg will see the sun totally eclipsed for 2 minutes 16 seconds.

As an added attraction, the Manitoba Planetarium (at 190 Rupert Ave., Winnipeg, Manitoba R3B 0N2) has prepared a special eclipse program. The planetarium started showing the program in October, and will continue until after the Feb. 26 eclipse. (Groups wishing to see the planetarium and eclipse presentation should book early!) For further information, contact Bill Peters at the Manitoba Planetarium, or Roy Belfield, 14 Argonne Bay, Winnipeg, Manitoba R2J 2K6.

About 130 miles west of Winnipeg lies Brandon, the second largest city in the province. Brandon is situated directly on the center line of the eclipse and will experience 2 minutes 51 seconds of totality. A large parking lot at the city's Keystone Centre will be available for observers and their equipment. You'll encounter considerable difficulty in getting motel or hotel accommodations in Brandon since the Canada Winter Games will be held there for the two weeks prior to the eclipse, attracting 200,000 participants and spectators. Most hotel and motel rooms will be reserved until after Feb. 26 for the games, and many participants will remain in Brandon for the eclipse. If you are planning a trip to Brandon, your arrangements should be cleared well in advance of your arrival! Mrs. Linda Robbins, General Manager, Brandon Chamber of Commerce, P.O. Box 548, Brandon, Manitoba R7A 5Z7, can provide you with more information about the city of Brandon and the Winter Games.

Other southern Manitoba cities to



This was the eclipse region almost a year before totality, as seen by a weather satellite. The clearest area is northeast of Lake Winnipeg, but lack of roads makes for poor access. This looks dismal, but clouds can thin and holes do appear, so take advantage and be mobile wherever you set up! NASA photograph.

consider for eclipse observations sites are Portage la Prairie, located between Winnipeg and Brandon on the Trans-Canada Highway, Bisset, Souris, Ninette, McCreary and Selkirk. North of Winnipeg are two large bodies of water: Lake Winnipeg and Lake Manitoba. The center line of totality runs across both lakes, and the cities of Gladstone, Lundar, Riverton, Winnipeg Beach, Victoria Beach, Gimli, St. Laurent and others will experience 2 minutes 45 seconds or more of totality. The city of Dauphin, north of Brandon and near Dauphin Lake and Riding Mountain National Park, is just south of the northern limit of totality; viewers there will see a total eclipse lasting 1 minute 32 seconds. The sun's altitude in Manitoba at eclipse time will be about 26 degrees.

Weather

At the outset, weather prospects may look hopeless. In the path of totality through the northwestern U. S. lies the cloudiest, foggiest, snowiest and coldest weather stations in the 48 contiguous states. From there, the eclipse progresses northeastward across ever colder regions of Canada, finally ending over the Greenland icecap — which at that time of year is likely the coldest spot on the surface of our planet! With a judicious choice of location, however, you can raise your chances of success to better than 50-50 — even higher if you can remain mobile during the hours before totality. To aid you in choosing an observing site, we'll tell you about the weather conditions likely to occur along the path of totality, both with an overview and more specifically, as well as providing some guidelines for evading bad weather should it happen on eclipse day. In addition, Table 1 tells you the chances for clear weather at selected locations.

Three major factors control the weather of the eclipse zone: the prevailing west to northwest winds, the types of air masses brought in by the prevailing winds, and the mountains. In late winter, the two important air masses are the cold, dry polar air that moves down from northwestern Canada, and the mild, moist air that blows on shore from the Pacific Ocean.

In crossing the mountain ranges of the northwestern U. S., the Pacific air lifts and cools, condensing its moisture into clouds, rain and snow. This makes the region between the Pacific coast and the continental divide in Montana the cloudiest of the entire eclipse path. As the air then descends the eastern slopes of the Rockies in central Montana, the resulting warming and drying thins the clouds out. These warm downslope winds, called *chinooks*, also occur east of the Cascades in central Washington and Oregon, leaving a relatively clear area in the heart of the otherwise cloudy northwest.

The Pacific air collides with the polar air along a boundary — called the *arctic front* — that typically runs from Alberta southeastward into the Dakotas. Frequently during winter, the storms that form in Alberta move toward the Great Lakes along this front. The counterclockwise air circulation around the storm pushes the arctic front northward on the leading (east) edge of the storm, and southward on the trailing edge. Large differences in the location of the front make the day-to-day temperature variations here (especially eastern Montana) the greatest in North America.

Since the Pacific air lost much of its moisture to the Cascades and Rockies, and the polar air was dry to begin with, the storms along the arctic front also tend to be dry. Snowfall is light at this time of year in eastern Montana, North Dakota, Saskatchewan and Manitoba. But now and then, one of these storms develops into a northern plains blizzard, notorious for the way the light snow is lashed by fierce winds.

Moving northeast from southern Manitoba, the track of the moon's shadow takes it out of the storm belt into the regions of Canada dominated by the clear, but very cold, polar air mass. Finally, after crossing a minor storm track along the west coast of Greenland, the moon's shadow leaves Earth in the northern part of the Greenland icecap.

Western Washington and Western Oregon

Here, where the Pacific air crosses first the Coast Range, and then the Cascades, lies the cloudiest areas of the entire path of totality. Winter weather is typically a succession of Pacific storms bearing rain and overcast skies, with brief clear spells between them. Sometimes the skies won't clear at all before the next storm strikes, but occasionally the clearings may last for days! After a storm, the mountain areas clear more slowly than the lowlands, making the Coast and Cascade ranges poor bets for viewing. However, small hills in the lowlands may be useful in getting above the morning mists.

Central Washington and Central Oregon

The Columbia Basin region just east of the Cascades has dry chinook winds, giving it the best weather prospects in the Pacific northwest, especially in the area between Yakima and Richland. While the 26 percent chance of a cloud-free view at Yakima may not seem too favorable, the clouds that do occur are often high and thin, raising to 45 percent the odds of at least a hazy view of the eclipse.

Common in chinook areas, but rare elsewhere, are "lenticular" clouds —

so-named because of their smooth, lens shaped appearance. These clouds happen when a range of mountains, such as the Cascades, creates a series of standing waves in the west-to-east air flow, much like the ripples seen in a creek downstream from a submerged rock. The clouds form at the crests of the waves, and although the wind may be blowing through them at hurricane speeds, the cloud formation usually moves very little from hour to hour. The importance of this for the observer is that the area of clear sky (or thinner cloud) *between* the lenticular clouds also moves very little, giving the mobile eclipse viewer a chance to find a "hole".

Eastern Washington, Oregon, Idaho, Western Montana

Between the eastern parts of Washington and Oregon and the continental divide in Montana lies another generally cloudy region. The weather patterns here behave about the same as along the Pacific coast, except that the Rockies are higher and colder, making the precipitation more likely to be snow. This area is only slightly less cloudy than the Pacific coast region, and the clouds persist more in the higher terrain than in the valleys.

Central Montana

Like the east slope of the Cascades, the eastern slope of the Rockies produces chinook winds and lenticular clouds. Here, extending from the continental divide 50 to 100 miles eastward, the chances of a cloudless view are about 26 percent, but you have a better than 50-50 chance of seeing some corona through generally thin clouds. Chinook winds, while warm, can present a problem to some observers. Blowing at speeds of 25 to 50 m.p.h., they can persist for days, and in some places just east of the mountains the winds occasionally exceed hurricane force. Moreover, the turbulent air during a chinook can reduce "seeing" — lowering resolution to no better than 5 or 10 seconds of arc.

While the arctic front normally remains to the north and east of this area, storms sometimes pull the polar air mass southwest as far as the continental divide. When this happens, the cold winds blowing up the eastern slopes cause heavy snowfall and lingering clouds, so a site to the east away from the mountains may be necessary.

Eastern Montana, North Dakota, Saskatchewan, Manitoba

With no large mountains or open bodies of water to influence the atmosphere (the lakes are frozen over at this time of year), the arctic front and the storms that move along it largely control the weather of the northern plains. Sometimes the polar air covers the entire region, while at other times the mild chinook winds blow as far east as North Dakota. The temperatures vary greatly; the reading at eclipse time in northeastern Montana could be anywhere from 30 degrees below zero Fahrenheit to 50 degrees above!

Storms usually move through the area from the west or northwest at moderate speed, and rarely last longer than a day or two at any particular spot. The clearing behind the storm is rapid and followed by northerly winds and temperatures dropping to around zero or colder. Clear skies then persist for a day or so before warmer southerly winds and increasing clouds herald the approach of the next storm. Because of these rapid day-to-day changes in the weather conditions, you should keep tuned to the local weather forecasts and be prepared to move if a storm is on the way.

Table 1
Probability of Seeing Corona

Place	Chances (%)	Temp. (° C.)
Astoria, Ore.	20	6
Portland, Ore.	22	6
Yakima, Wash.	36	2
Walla Walla, Wash.	27	5
Lewiston, Idaho	27	3
Missoula, Mont.	28	-2
Helena, Mont.	39	-3
Great Falls, Mont.	42	-2
Billings, Mont.	41	-1
Havre, Mont.	43	-6
Glasgow, Mont.	44	-7
Miles City, Mont.	45	-3
Williston, N.D.	46	-7
Estevan, Sask.	44	-8
Brandon, Man.	45	-10
Dauphin, Man.	48	-11
Winnipeg, Man.	47	-10
Red Lake, Ont.	53	-12
Island Lake, Man.	60	-16
Trout Lake, Ont.	51	-16
Winisk, Ont.	56	-20
Inoucdjouac, P.Q.	57	-21
Frobisher Bay, NWT	53	-23
Umnak, Greenland	35	-13
Greenland icecap	32	-40

Although the northern plains area has no major mountain ranges, there is one area — Riding Mountain, 70 miles north of Brandon, Manitoba — with enough elevation to affect the local weather. After a storm passes, the clouds can linger a half day or longer over Riding Mountain, while nearby areas have cleared.

Because of its extent, it's unlikely that the entire northern plains section of the eclipse path will be clouded out. With no mountain passes to slow traffic, and good roads, this area offers by far the best opportunities to the mobile observer.

Ontario and the Canadian Arctic

Moving northeastward, the eclipse path leaves the zone of most frequent storm activity. Although storms can, and do, cross the arctic at this time of year, most commonly the entire region is covered by clear and bitterly cold polar air. The usual form of precipitation is ice crystals falling from a nearly transparent cloud layer. Winds tend to be light, except along coastlines where blowing snow may be a problem. The chances of clear skies are the most favorable of the entire path of totality; unfortunately, the area is not very accessible.

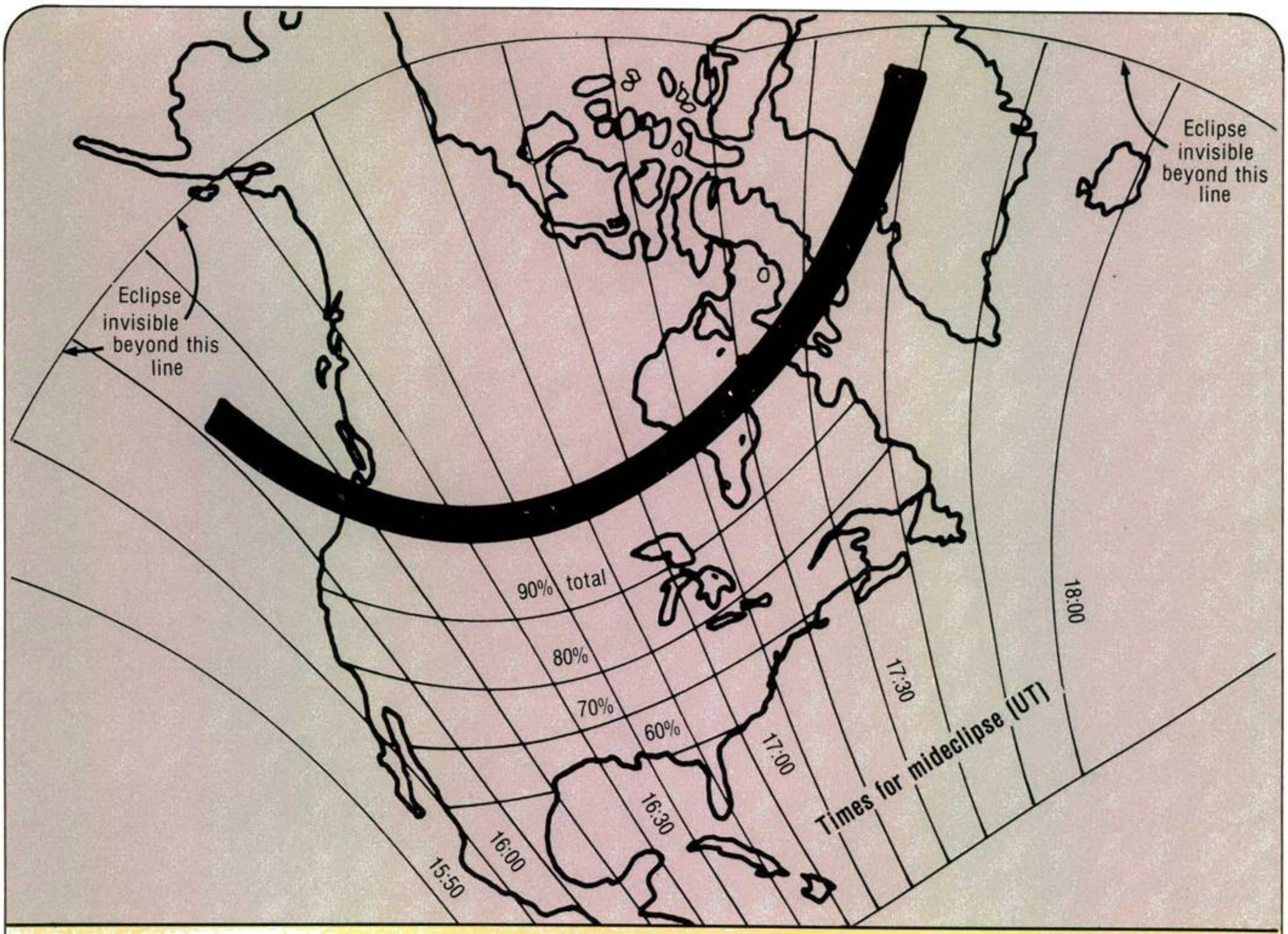
Greenland

With a minor storm track up the west coast and open water offshore, the coastal area of Greenland usually clouds over. At 10,000 feet, the icecap remains above much of the murk, but frequently higher cloudiness minimizes the chances of a clear view of the setting eclipsed sun. Considering that temperatures of 80 degrees Fahrenheit below zero have been recorded in late February, the Greenland icecap is definitely not a recommended observing site!

Where then is the best location to view the eclipse? Because different observers have different needs, no simple answer can be given. Residents of the Pacific Northwest who don't want to travel across the country can still double their chances by taking a short trip to the Columbia River Basin. The fairly mild temperatures and sunny skies of central Montana may appeal to some observers, but chinook winds may cause problems for those with delicate instruments. By using the weather forecast to pick a site the day before the eclipse, a mobile eclipse watcher should have an excellent chance in the northern plains region. The stationary observer would do better to go as far to the northeast on the eclipse track as possible, trading off comfort and convenience for clear skies.

All in all, the northern plains will probably appeal to most watchers. Remember, though, that the weather conditions described here are *typical* conditions for that time of year. Late February, while still winter, is close to the transition time to spring. If spring comes early, storm tracks will be north of their usual position, leaving clearer skies in the Pacific Northwest and more clouds in southern Canada. Eclipse day itself could bring anything from perfectly normal weather to "first-time-in-this-century" storms. We hope we've helped you make long-term plans, but for best results, be prepared to change them as second contact approaches!

Daniel Koehler is a student at the University of Wisconsin — Whitewater. Richard Keen is a professional meteorologist in Boulder, Col.


Eclipse invisible beyond this line
Eclipse invisible beyond this line
90% total
80%
70%
60%
15:50
16:00
16:30
17:00
17:30
18:00
Times for mideclipse (UT)

How to Watch a Partial Eclipse

If you can't travel to see totality but want to see *something*, or if you want to know what to do during the partial phases, here's an idea: Why not try projecting an image of the partly eclipsed sun? *It's the safest way to observe the sun*, eclipsed or not, and many bystanders can crowd around to watch. You could end up giving an astronomical minilecture to a curious crowd!

You can use any optical aid to project the image, but to insure everyone's safety, there are some precautions to follow. *Never, never look through binoculars or a telescope at the sun*, except during a total eclipse. 99.999 percent isn't enough. *It has to be total!*

To project the image, set up your equipment and align it with the sun by looking at its shadow on the ground. When the shadow of your instrument is as small as possible, hold up a sheet of cardboard behind the eyepiece. A moment's fiddling will center the sun's image if it isn't there right away. Focus normally.

Shazam! You now have an image to amaze the curious and impress the on-lookers. You can make the image less washed out by putting up a second sheet of cardboard to shade the projection screen. A low power eyepiece will give you less trouble in holding the image steadily centered.

Supposing you don't have a telescope or even binoculars. Can you still see the partial phases safely? Yes — with the ultralow cost, handy-dandy pinhole eclipse projection machine! This astonishingly simple device (construction details are on page 55 in this month's Equipment Atlas) will show you the partial phases easily and clearly. Just hold it up perpendicular to the sun's rays and put a viewing sheet behind it.

Because the "optical system" is very low power, the image size isn't large, but moving the viewing screen farther back from the pinhole will make the sun's image larger (though also dimmer). Remember, *don't look through the pinhole*; just project with it!

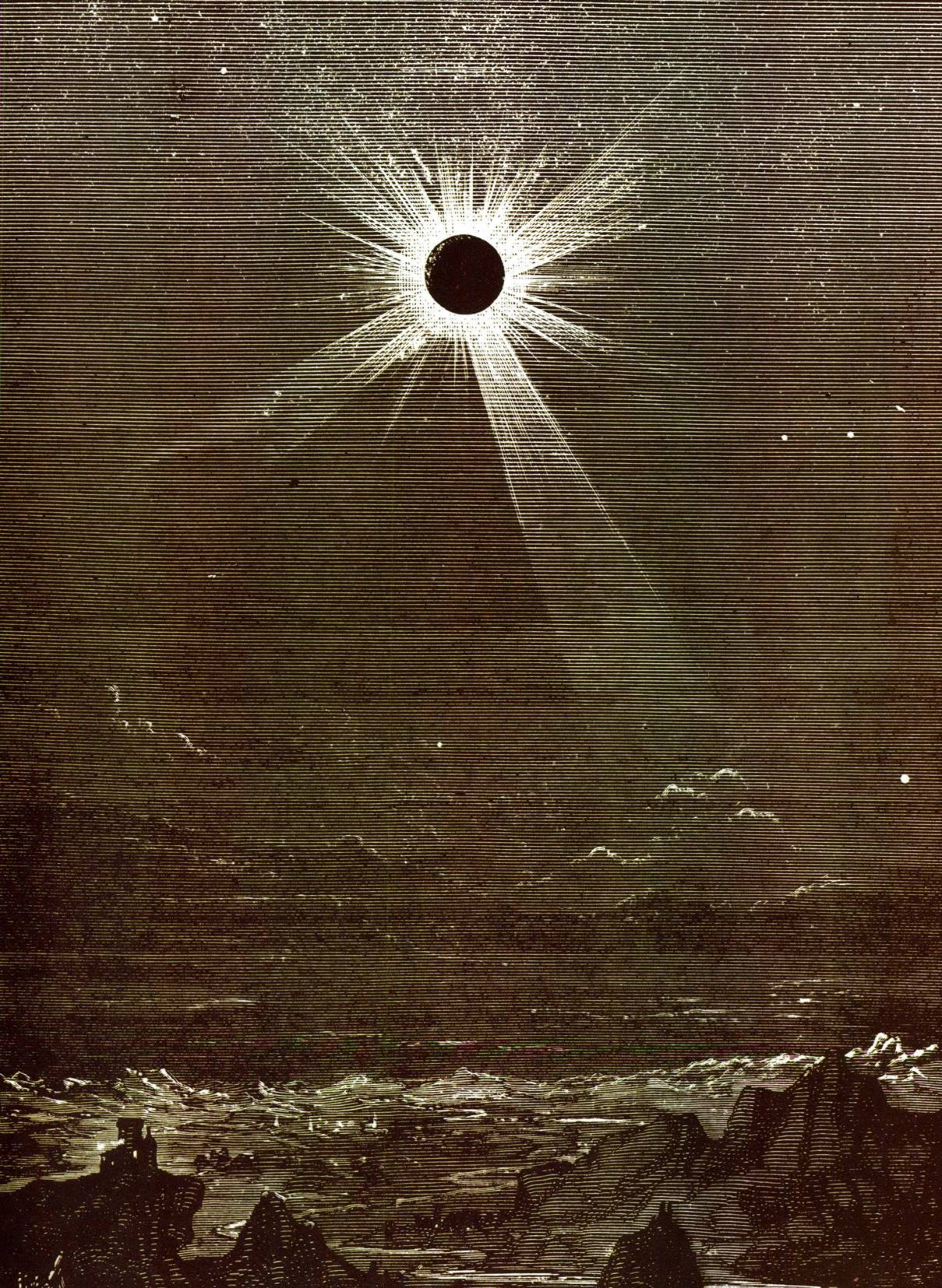
What can you see observing a partial eclipse? Depending on how close to the eclipse path you are, you'll see the moon cover up a greater or lesser part of the sun. In some areas, the maximum amount taken out of the sun will be just a little bite; in others, where the eclipse is 99 percent total, most people in the street will notice something strange going on.

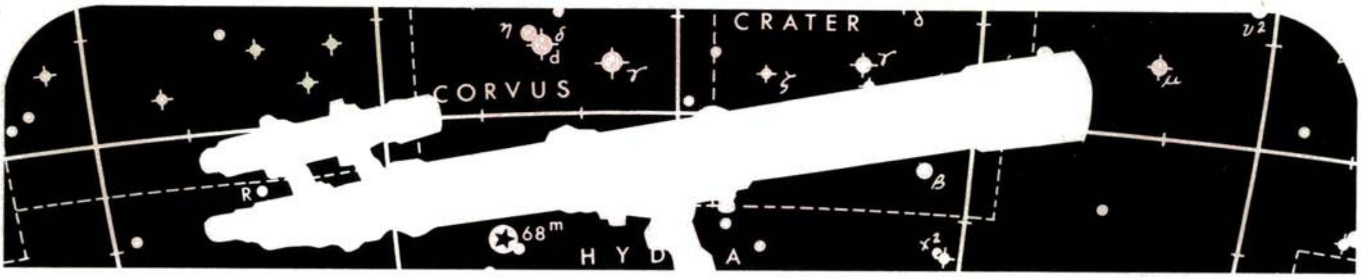
With your projection viewer (whatever the type), you'll see the moon slowly advance across the disk of the sun. The total time the moon is on the sun's disk varies according to how total the eclipse is. Near the line of totality the duration will be about two hours, but far away from it, the eclipse takes but a few minutes.

If the sun's disk has many sunspots on it, you'll be treated to the sight of watching these gobbled up and then uncovered by the moon. You might try sketching the effect!

If your projection system has moderate powers, you may see minute irregularities in the moon's limb. Mountains on the edge of the moon make tiny bumps in the round black circle. If you're in the path of totality, the valleys between these mountains will show you the celebrated "diamond ring" effect. When the disk is all but covered up, sunlight will stream through the valleys, making bright points on the limb of the moon, resembling a diamond ring!

Wherever you are, there'll be something to see on eclipse day!





Winterize Your Expedition

Every eclipse expedition requires a certain amount of planning and preparation, but seldom more than this one! Many people will be driving from far and wide to see the glorious sight. For the typical observer, the expedition will last several days and will involve moving delicate equipment many hundreds of miles. Because of the time of year — winter — and the unpredictable weather, you'd be wise to make your plans on a "worst case" basis.

The worst case approach has a doomful sound to it, but serves to help you plan for the unlikely emergency. More probable will be an eclipse day that dawns bright and clear with the temperature in the 20s. The sun will blaze out of a deep blue sky and the vault above will be magnificent.

An eclipse seen under these conditions will long be remembered for its splendor by those present. Don't let the warnings discourage you; it's only the common sense approach to northern winters.

What is the *worst* thing that could happen? Being clouded out? Not at all. You could have your car break down at dusk on some little traveled road, just as the wind picks up, the temperature drops to -20 degrees Fahrenheit, and the snow starts blowing! Would you be prepared for such a happenstance? It may sound sort of melodramatic, but the situation isn't all that uncommon on the prairies in winter. It *could* happen to you.

An old engraving shows what was seen visually at the total eclipse of July 29, 1878. Beginning at the upper left of the sun and going left to right are Mercury, Regulus and Mars. Castor and Pollux are to the right, while Procyon is directly below the sun, and Venus hovers by the right hand edge. The picture conveys dramatically the difference between naked eye impressions and photographs. Here the coronal streamers are the most prominent feature; lack of contrast usually hides them in photographs.

Having decided to go, the next course of action is to prepare yourself and your car thoroughly. Check out the car's condition overall. Make sure the radiator, windshield washer and gas tank have all been antifreeze treated. Get the oil changed if it hasn't been done recently. See that the gas, oil and air filters are clean. Have you got chains or snowtires? Jumper cables? A shovel and sand? Candles and flares? A tow rope? Is your battery topnotch? A few spare blankets or old sleeping bags put into the trunk could keep you warm while you wait for help to arrive. They can also be used to get a tire out of the hole it's spinning in, should you get stuck.

If you live where winter means ice and cold, you'll have winterized your car already to some extent. The danger here is that you may be tempted to head off for the eclipse just as you are. Don't! Have your car fully checked over. If you've been planning some repairs, do them now! Your car may work fine on local trips, but might not if you go a couple thousand miles.

When you've prepared the car, how about yourself? You'll need lots of clothing, but if you have a medium weight coat over many light layers and over thermal underwear, you'll be nice and snug. In the event you get too hot, you can easily shed a layer or two without becoming cold. Bear in mind that you're not going to be very active except during those frenzied few moments of totality.

If you wear two pairs of socks (one thin, the other thick) inside your boots, it'll keep your feet comfortable. The important thing is to have enough room inside the boots that the two pairs of socks don't shut off the circulation to your feet. If your socked foot slides into the boots without strain and you can wiggle your toes comfortably, then you have enough room.

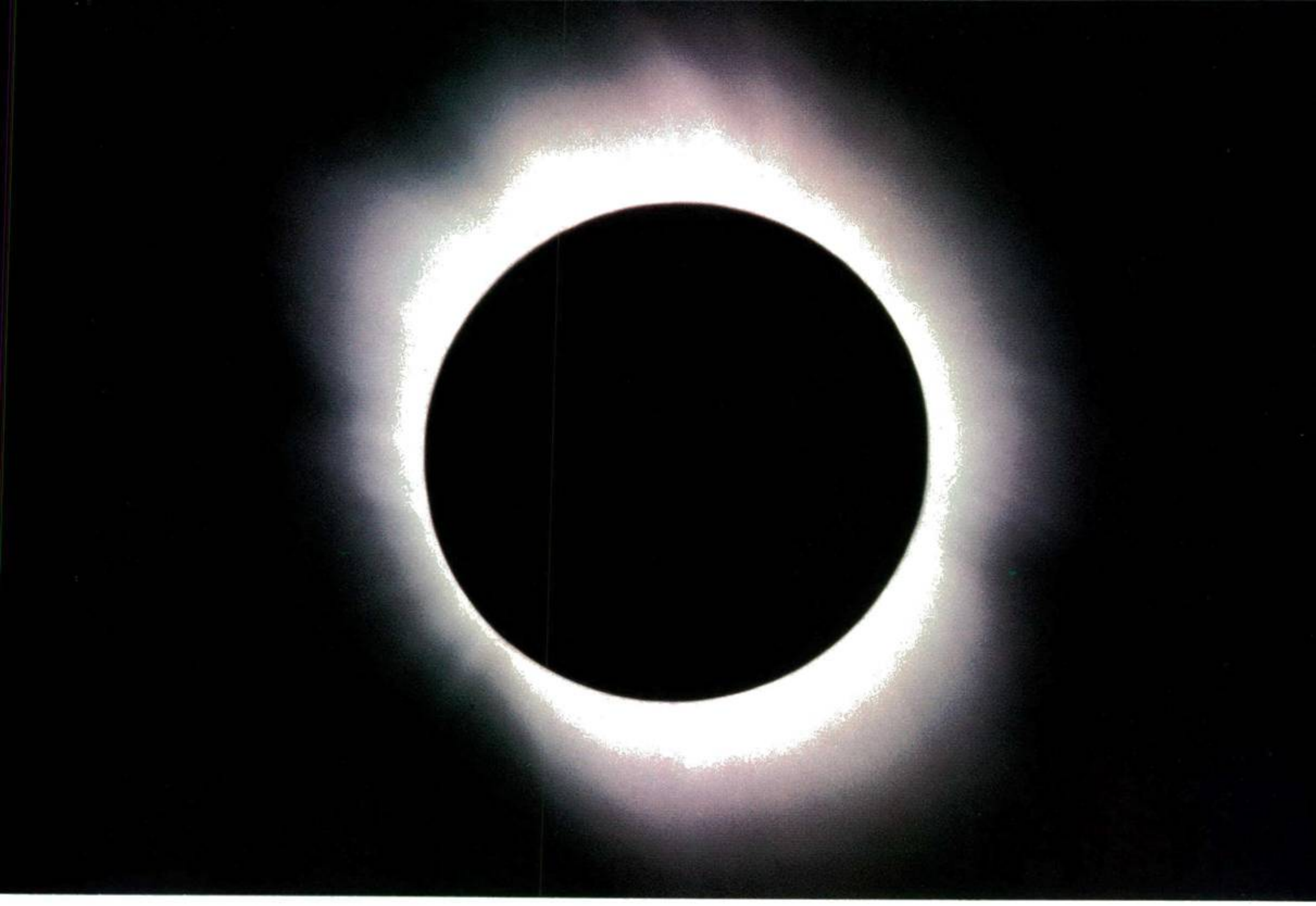
Keeping your hands warm may be more difficult. Heavy mitts would do the trick, but then you'd have little ability to manipulate anything. Lighter gloves afford you maneuverability, but you'll get cold. A good compromise is to have light gloves inside a large pair of heavy mittens. You'll stay warm and the outer mitten can be stripped off in a hurry to allow fine adjustments of your equipment.

For headgear you'll want a ski cap with built-in face mask or a balaklava, especially if the wind is blowing. A wide, tightly knit scarf will give you something snug to wrap around your neck.

When it comes to putting your equipment into shape for the trip, you'll have to make a decision based on economics. Most mechanical objects like mountings, cameras and binoculars can be winterized, but the cost isn't trivial. Winterizing means a technician takes the item apart, cleans out all the grease and oil, and then reassembles it either with lighter weight equivalents or no lubrication at all. When your equipment is returned to normal use, the reverse process has to be done. This is expensive and probably unnecessary.

Unless you have *very* delicate items, your eclipse gear will likely survive just as it is. But you should remember a few tricks in handling things. For example, film becomes brittle at cold temperatures, so wind the film e-a-s-i-l-y between exposures. (This precaution also minimizes the chance of a static electric spark marring the film — winter air is very dry and promotes static electricity.)

In the cold, you'll find the grease of your mounting or tripod head has stiffened greatly. Don't count on



Much of the structure visible in the photograph would be far more noticeable than this to a visual observer. Photographs reduce the contrast greatly by changing an image of light into a print, with most of the loss happening in the film-to-paper transition. Still, the final print is a souvenir that will retain its clarity far longer than a memory, however splendid. Photograph by Raymond Couldier.

having smooth motion from your drive mechanism! If the works are sticky at room temperature, it could become a serious problem on eclipse day. Try to loosen any adjustment screws until they turn freely, and then tighten lightly. You don't want to be yanking on the thing during totality to make it work right! Practice outside in the cold before the trip.

Try not to breathe on any optical parts, for doing so will instantly coat them with an icy rime that will ruin the image definition. To some extent eyepiece fogging is unavoidable because your warm moist eyeball will humidify the air next to the eyepiece. To combat this, keep eyepieces in your pocket, when not in use, perhaps also putting in a commercial pocketwarmer.

If you have access to a 110 volt outlet, you can use a hair dryer to send a blast of dry air across fogged optics. To get the air to come out hot, you may have to put the whole dryer under your coat while it's running, since the elements aren't made to heat up air coming in at cold temperatures. (It will feel good, too!)

Roadside sites may have soft snow shoulders. To get around this problem, you could construct a platform of 3/4 inch plywood reinforced on one side with 2x4s. This will prevent tripod tips or mounting legs from sinking into the snow. The size of the platform depends on your equipment, but don't plan to stand on it yourself! Your shifting weight would make the sun's image lurch in and out of the view!

A radio receiver is a must to keep you up-to-date on weather forecasts. A shortwave receiver will provide time signals as broadcast by WWV or CHU. WWV is at 2.5, 5, 10, 15, 20 and 25 MHz. CHU (the Canadian time service) is at 3330, 7335, and 14670 kHz. A CB radio could be a great help in an emergency, but a special license is needed to operate one in Canada. (For information, write to the Manitoba Department of Tourism, 200 Vaughan St., Winnipeg, Manitoba R3C 1T5.)

To see this eclipse at its best, you'll do well to bring low power instruments — maybe nothing more than your eyes! Gazer's Gazette this month lays out what you can see with various instruments, so here we'll just make a few suggestions.

An eclipse is an event of tremendous scope that involves the whole of the visible sky. If you zero in too close on the eclipsed sun, you'll trade a lot of the spectacle for great detail. Take the time and equipment to stand back and let the awesome sights roll over you. We think you should use binoculars or a rich field (wide angle) telescope. Both have low powers and consequent wide fields of view; the RFT allows you to look closer if you want by changing an eyepiece. Binoculars generally are cheaper and more portable, and many of you have them already. Neither one requires handling much different from the usual, but here are a few hints: The mounting for your instrument should be as steady as possible. Try to set up the day before, aiming the equipment at the sun at the proper time, 24 hours early. If you cannot leave the instrument set up overnight, clearly mark the position of the platform (if you're using one) and the placement of the tripod legs.

Binoculars benefit greatly when mounted on a tripod. Many camera stores sell an attachment that clamps

EQUIPMENT ATLAS *continued next page*

EQUIPMENT ATLAS

onto the center shaft of binoculars and has a threaded socket for the standard 1/4-20 tripod screw. If you don't have one of these, try using wide rubberbands or freezer tape to attach the binoculars to the tripod head. Be sure to do the attaching inside; tape has little glue, and rubberbands act like taffy when cold. (When removing them after the eclipse, bring the rig inside and let it warm up before you start to peel off the tape or bands.)

Looking at the sun during the partial phases is as dangerous as when it is totally uneclipsed. To watch the gradual covering of the disk, use a pinhole projector, made as follows: Take a sheet of cardboard of any convenient size (8-1/2 x 11 inches is okay). In the center, cut a hole a few inches in diameter. Cover the hole with a piece of aluminum foil and tape it to the cardboard. Then with the foil laying flat on a hard surface, prick a tiny hole in it at one spot with the point of a ordinary sewing needle. When you hold this up square to the sunlight, you'll see an image of the sun thrown onto any flat surface behind. It's safe, simple and easy!

Now, with yourself, your car and equipment duly cautioned and properly prepared, off you go! Good luck and good weather!

GAZER'S GAZETTE

continued from page 42

observation will be necessary to indicate movement. The quiescent ones will look like tiny spikes sticking up from the surface, and will change only slowly.

You'll lose just about all the corona at 120x. The black disk of the moon more than fills the 20 minute of arc field. Nevertheless, this power rewards you with a close look at the sights, provided you put the disk off center.

You may see some prominences hovering unsupported in the corona. Many times they've been observed by professional astronomers to erupt both up from the surface and down to it. A special type of telescope was invented to allow examination of the inner corona outside of eclipses, and time lapse photography through these complex and very expensive instruments have revealed these motions in the prominences. You're lucky, though: All you need is your simple telescope — and an eclipse!

Suppose you go the limit! What'll you see at 250x? Well, not much of the sun as a whole! You'll do best to put the disk at the edge of the viewing field and concentrate on examining prominences. Some will be very small, others much more impressive. Watch closely and you'll see the edge of the moon moving to cover up the eastern prominences and uncovering those on the west.

As the end of totality approaches, be very careful not to look at the whole of the disk or the western part. The sudden return of the sun's bright photosphere could blind you easily. Someone in your eclipse party should be timing the event at your site and should call out when 10 seconds remain. With five seconds to go, you'd do best to look only with your naked eyes, not through the scope or binoculars. The diamond ring effect happening at both ends of totality is very pretty to see anyway.

Totality's over! For most people, so is the eclipse, but you ought to stop and notice the strange events of returning daylight as they happen in reverse order from the onset of darkness. Besides, if you were dark adapting your eyes before the event, you wouldn't have seen them!

What's the best power to use? They all show somewhat different aspects of the eclipse, so in a very real way, there is no "best" power. However, especially if it's your first eclipse, stick to the lower powers — 15 to 60x. Lower powers will show you the splendor of the whole event rather than magnify just one tiny part of it. And remember to give 1x — your naked eyes — a good look too.

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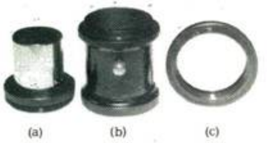

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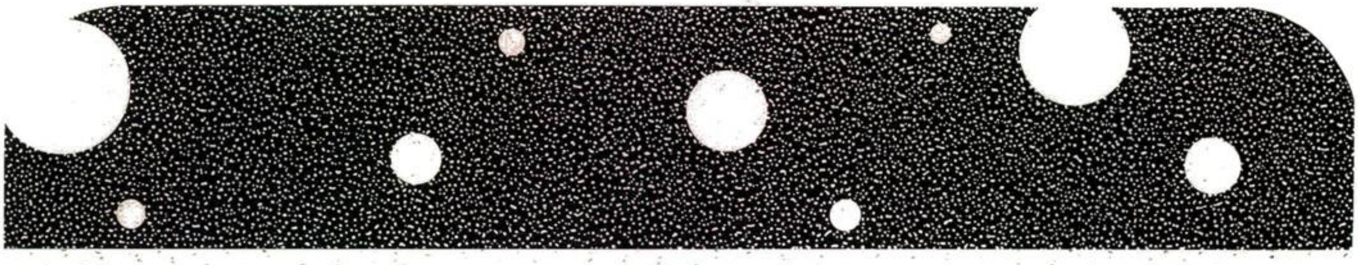


STELLAR FRONTIERS

Mars: A Planetary Paradox

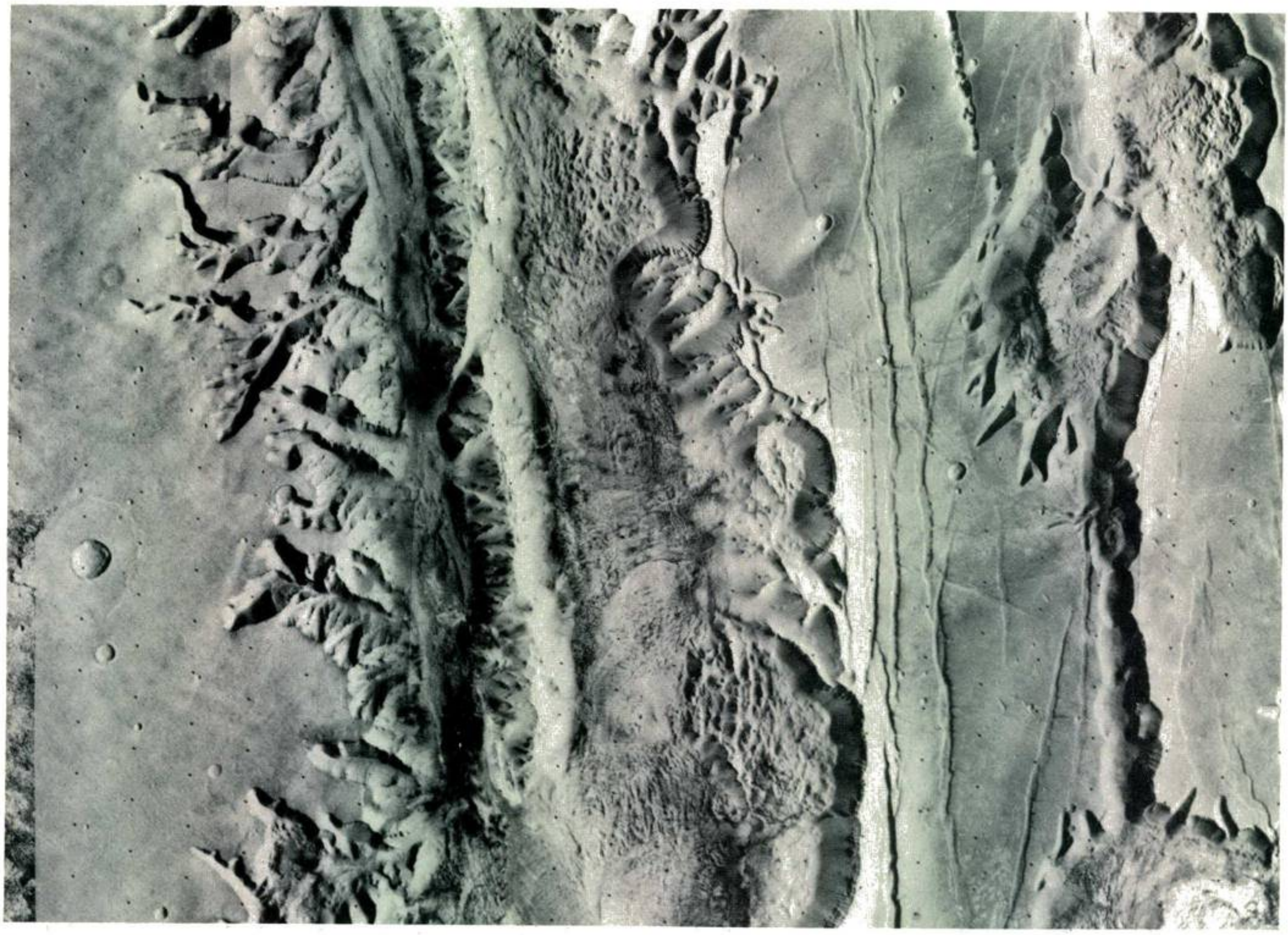
by
Herbert Frey

Mars is a geologic paradox, a mixture of moonlike and Earthlike structures. The entire southern hemisphere is an ancient, heavily cratered surface — like the battered highlands of the moon. Here thousands of craters — including giant impact basins — have been preserved from the earliest history of the planet, changed only slightly by the drifting sand and windblown dust. To the north, immense volcanic flows spread out in plains like those of the dark lunar maria. There the craters are fewer and sharper, attesting to the younger age of these lava fields. Were these the only surface features of Mars, the planet would indeed be moonlike, having little in common with Earth except its thin atmosphere and windborne erosion.

But clustered about 110 degrees west longitude are giant volcanic mountains of a sort not seen on the moon. These giant *shield volcanos* are like the islands of Hawaii: broad but high constructs produced over long periods of time by the repeated outpouring of lava from deep within the planet. Smaller cones are also visible on the higher resolution pictures of the Mariner and Viking Orbiters; these, as well as their giant cousins, indicate a kind of geologic activity which the moon never knew.

The largest of the Martian shield volcanos are much larger than those of Earth. They sit atop a broad swell in the crust, where the surface has been uplifted by the force of slowly churning molten rock deep within Mars. Such crustal uplifts exist on Earth as well; they are major sites of volcanic activity and often herald the beginning of breakup of the crust into plates or blocks which are the major tectonic feature of this planet. The uplifted crust, stretched by the forces applied to it, breaks typically into a three armed pattern. Part of the resulting rift may be wedged apart by molten mantle material forced up into the crack. Continued spreading of such a rift eventually leads to the opening of a small sea. The Red Sea on Earth is an example of connected rifts that have spread to form a small ocean; continued growth by addition of new oceanic crust along the rift axis widens such bodies into Atlantic sized oceans. In the process, the continental blocks bordering the rifts are slowly pushed apart, at a rate something like two to three centimeters per year (one inch per year). This — in brief — is the style of Earth's modern evolution, called *plate tectonics*. It is responsible for the rearrangement of the continents that has occurred over the last 200 million years (and probably longer). It is also the cause of most of the world's major earthquake and volcanic activity. This activity occurs principally at the boundaries between plates, where they separate (at midocean ridges) or where they come together and collide (such as the west coast of South America). The collision between major continental plates may raise huge folded mountains like the Himalayas (which are a product of the convergence of India with the large Eurasian plate).

There are n folded mountains on Mars. This suggests that past plate motions most likely did not exist. At the very least there could not have been major collisions between continental plates. Had



there been, it is unlikely that the weak erosion of Mars, which has been unable to erase the ancient highland craters, could have removed all traces of a Himalayan type mountain belt. There are also no features on Mars that resemble the spreading plate boundaries like Earth's mid-Atlantic ridge or East Pacific rise. On our planet these ridges form the most impressive set of linear mountains known, rising sharply from the deep ocean floor. No such linear chains have been observed on the now fully mapped surface of Mars.

What does exist on Mars is a set of impressive *rift valleys*. The valleys are individual *graben*, or down-dropped blocks of crust bordered on each side by roughly parallel faults. Collectively called Valles Marineris (valleys of Mariner, for the spacecraft which first discovered them), these canyons are located slightly south of the equator, just east of the major shield volcanos, along the downhill slope of the largest crustal swell on Mars. Individual canyons are up to 200km wide and several hundred kilometers long. Erosion has caused them to merge into a complex region near 80 degrees west longitude, 5 degrees south latitude. Running water from previous warm epochs of Martian history, as well as giant landslides recently seen in Viking high resolution pictures, have widened the canyon walls and obscured the detailed traces of the original faults.

The western end of Vallis Marineris was photographed by Viking 1 in late August 1976 during the orbiter's 62nd revolution around Mars. Viking scientists considered this region a priority target, and had already obtained pictures on two previous orbits which, when combined with this picture, gave a stereo view. Although the origin of the faults is not known, they are altered by a combination of wind excavation and slow downhill "mass wasting" of debris. NASA photograph.

The overall pattern is clearly related to the large crustal swell in the Tharsis region, where the largest of the Martian volcanos are located. Crustal uplifting in this area caused severe stresses in the brittle outer lithosphere of Mars. Fractures resulting from this stretching have been mapped by William Hartmann of the Planetary Science Institute and Michael Carr of the U. S. Geologic Survey. Both agree that the Vallis Marineris rift canyons are the largest of the fractures associated with the Tharsis Uplift.

The connected rifts of the Mariner valleys may be considered the beginning formation of a plate boundary on Mars. This is a region where the crust is being ruptured due to internal circulation of the thick, hot, plastic mantle of Mars. But the process has only begun. Elsewhere around Mars there were no other major rift valleys with which this one might have connected to form a complete plate boundary. There never were isolated blocks or plates on Mars; without plates there was, of course, no plate motion. Mars has only those features which indicate the beginning of plate tectonics (uplifts and rifts). We might describe the state of Martian evolutionary development as "*incipient* plate tectonics".

Mars is therefore an intermediate planet — one with mostly lunar type surface features which, in a few areas, have been altered by Earth style geological processes. The planet looks like a moon trying to become an Earth. The important point is this: Mars shows us that modern Earth type tectonic processes can develop out of a world whose early evolution was much like that of the moon.

There is a pattern to the devlopment of the terrestrial planets. The moon — the smallest Earthlike body in the solar system — is also the simplest. Its surface can be described as one largely changed by impact and impact related events. A global crust formed early in lunar history; this resulted from the melting that accompanied the formation of our satellite. Upon cooling, lightweight aluminum and calcium rich rocks separated from the melted layer and formed a planetwide surface layer. This crust was severely battered by the debris left over from the formation process. Among these impacting bodies were some whose great size created giant impact basins hundreds to thousands of kilometers across. These depressions were later flooded by lavas generated in the hotter interior of the moon, which slowly worked their way to the surface through the highly fractured sub-basin crust. Following the meager eruptions of the dark mare lavas — which ended three billion years ago — lunar geologic history came to an end.

For most of Mars the same sequence of events must have occurred. Large and small impact craters formed in what was probably a global crust. Vast lava plains erupted over long periods of time to fill the dominantly low lying parts of the planet. But Martian history did not stop there. Twice as large as the moon, Mars had an extended evolutionary development that included uplift of the crust in at least three places, and extensive fracturing and rifting of the crust in one region over a long span of time. Unlike the still larger Earth, however, this rifting has not led to plate formation and plate motion. Over all its history, Mars has accomplished what probably happened early and very quickly on the young Earth. Plate tectonics on our very active planet may well have developed out of a lunar or Martian type world, but if so it was more than three billion years ago.

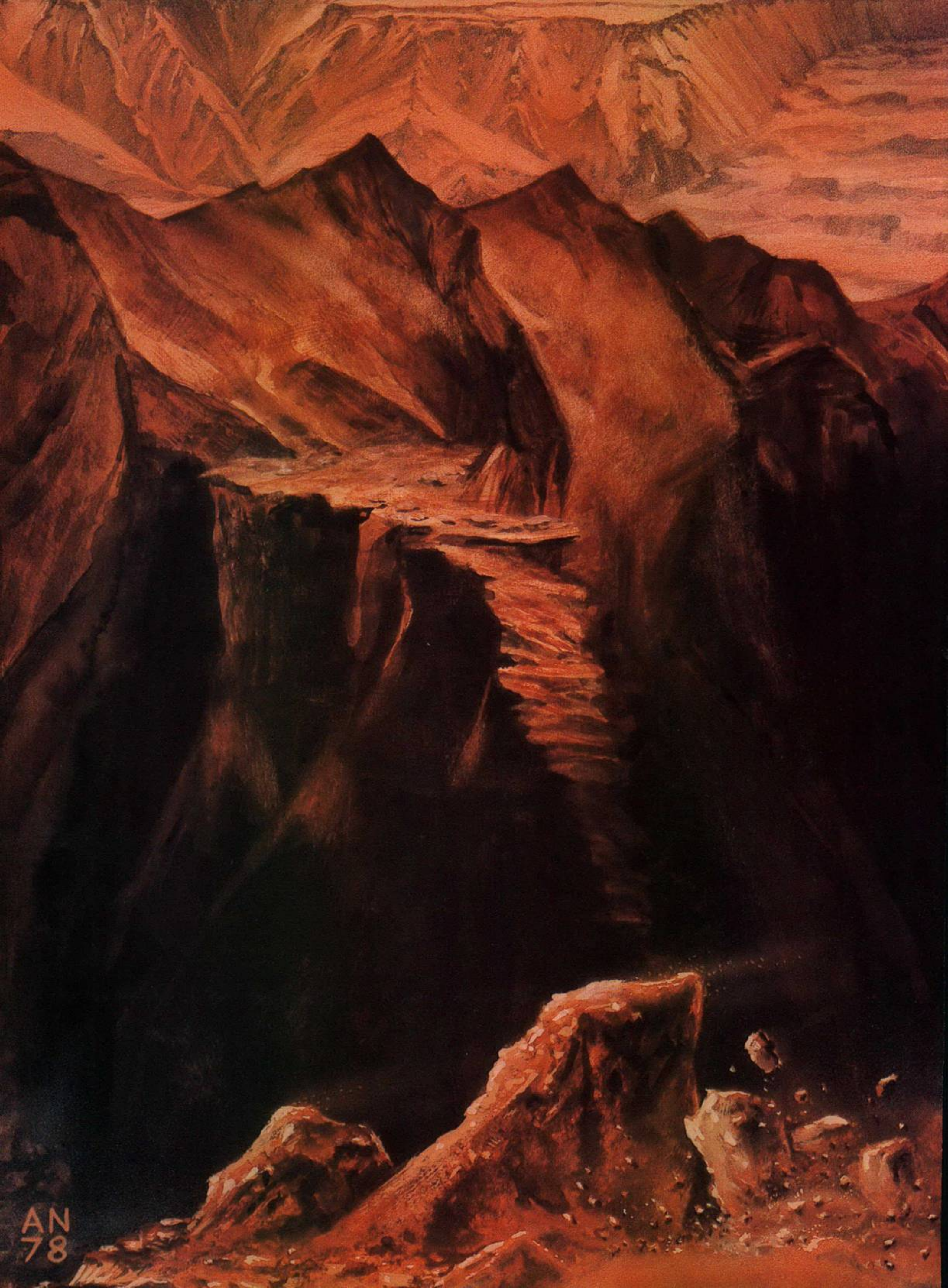
What of the future? Will Mars continue to develop, as did Earth, and finally produce plates that move about? Will the future bring spreading ridges and folded mountains? Is the activity of Mars simply lagging behind that of the much larger Earth? Or, alternatively, has Mars developed as far as it can?

There are a number of reasons to think that Mars has indeed passed its peak of activity and can evolve no further into an Earthlike planet. First is the record of the activity on Mars itself. While there are lava flows on the planet too young to date (by the standard method of counting craters), they are few. Most of the Martian volcanos are extremely old — far older than most of Earth's crust. The ocean floor of Earth, which occupies about 60 percent of the globe, is everywhere younger than 200 million years old. On Mars, only small parts of the surface can be said to be this young. *Most* of Mars is an ancient relic of the distant past. There has simply not been enough geologic activity to produce the huge volumes of new crust we see in Earth's oceans. Likewise, many of the major rift valleys are also old, and there is no indication of very recent faulting or rifting. In short, evidence suggests that the recent activity is significantly less than that of some time ago; Mars may be winding down.

This is to be expected when the driving force behind planetary evolution is examined in detail. What makes the internal engine of geologic development run? Quite simply, the answer is *heat*. The greater the heat content of a planet, the more vigorous will be the planet's activity, which is simply an attempt to lose that heat.

Most planets start their evolutionary development at high temperatures. This heating at origin comes from a number of sources. Among the most important is *accretional heating*, due to the growth of the planet itself. When nearly fully grown, a planet has nearly its full gravity field. As a result, the last 10 percent or so of the mass being added — or *accreted* — to form the planet comes in at very high velocities, accelerated by the planet's large and growing gravity field. The resulting impacts release huge amounts of heat. Because so many impacts of this type occur in a relatively short period of time — probably only a few thousand years — the temperature of the body is raised close to the melting point. This clearly happened for our moon, as indicated by analysis of samples brought back by the Apollo astronauts. Heating led to melting of at least the outer parts of the moon, and in turn to formation of the original crust. For any larger planet, the effect of accretional heating would be greater because of the greater acceleration of the incoming bodies by the larger gravity field of these planets. Earth probably melted completely at its origin, due to this and other processes.

Any body this hot attempts to lose its heat to the cold of space; that is, it attempts to come into an equal temperature state with space. At the surface of a planet, heat is lost very rapidly by *radiation*. Through the brittle, solid lithosphere, heat is lost by *conduction*, a rather slow and inefficient process. What happens in the deep depends on the physical state of the rocks at depth. If they are completely or even nearly molten, then *convection* can occur. Hot material will itself carry the heat toward the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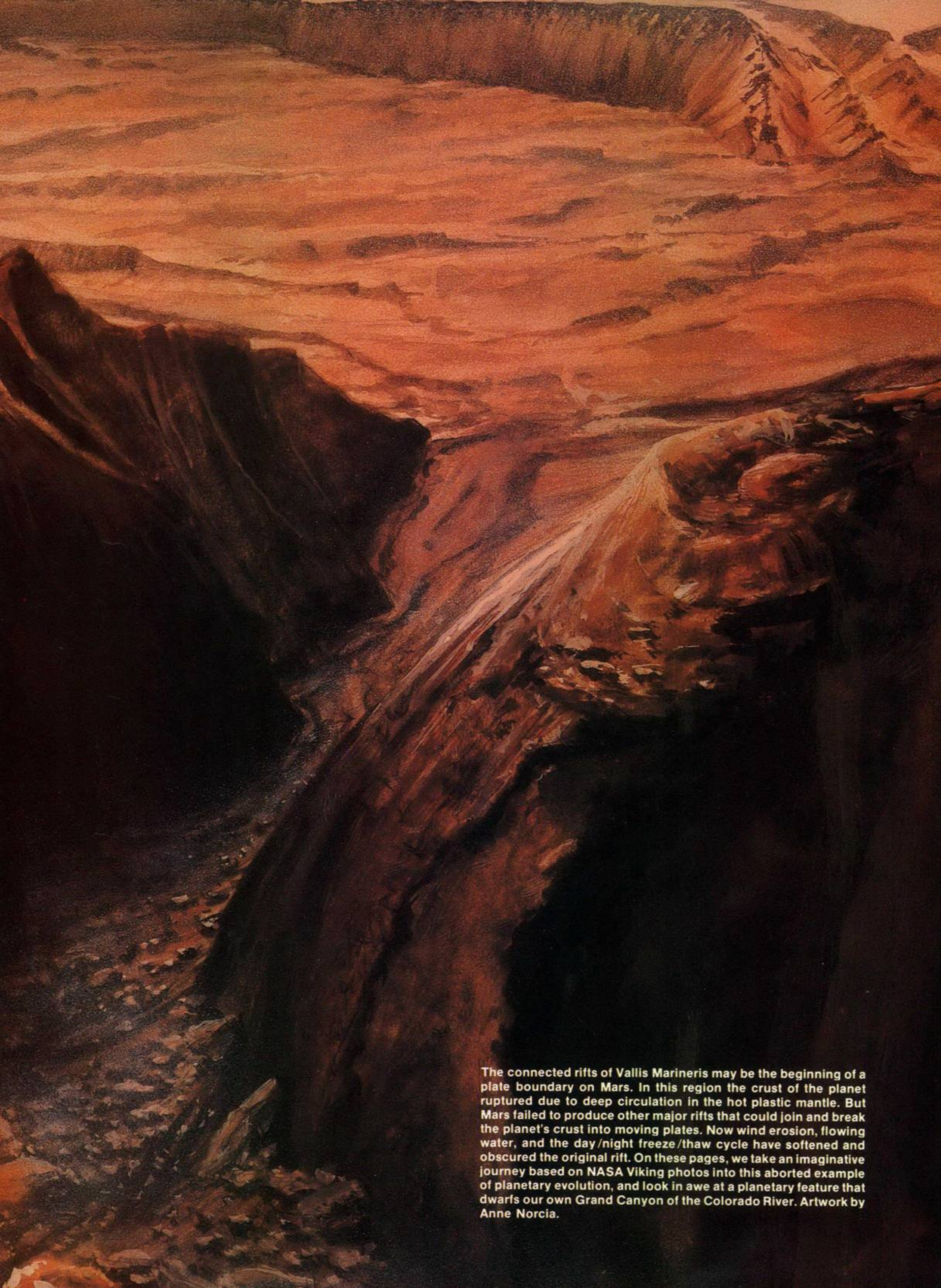

The connected rifts of Vallis Marineris may be the beginning of a plate boundary on Mars. In this region the crust of the planet ruptured due to deep circulation in the hot plastic mantle. But Mars failed to produce other major rifts that could join and break the planet's crust into moving plates. Now wind erosion, flowing water, and the day/night freeze/thaw cycle have softened and obscured the original rift. On these pages, we take an imaginative journey based on NASA Viking photos into this aborted example of planetary evolution, and look in awe at a planetary feature that dwarfs our own Grand Canyon of the Colorado River. Artwork by Anne Norcia.

surface. The motion of this material is what drives the motion of the plates on Earth. If the planet is solid, then the less efficient conduction must transport the heat.

It is not enough for a planet to simply lose the heat of formation. Heat is also added slowly over time by decay of unstable radioactive elements such as uranium, thorium and potassium, which are part of the terrestrial planets.

Which planets lose their heat more rapidly — large or small ones? The important parameter is the heat loss over heat gain, and not just the temperature of the body. Heat gains (from radioactive decay) depend on the total *volume* of radioactive material in a planet. Heat loss depends ultimately on the radiating *surface area* of the planet. Therefore, how fast a planet cools off depends on the ratio of the surface area to volume of the planet. Small worlds, like the moon, have a larger surface area relative to their volume than do larger ones like Earth. The moon should cool off and solidify faster than Earth. Its geologic activity will stop at an earlier time, because there will no longer be enough heat to melt rock, form lava, produce volcanos or stretch the crust. For Earth, heat will persist at higher levels longer, and the planet will remain much more active for extended periods as it tries to lose its heat. Because it is so hot, Earth can today have internal convection currents of molten material, which uplift and rift the crust, forming plates and moving them about. The now cold moon, by contrast, is solid and rigid throughout most of its volume.

Mars is intermediate in size, and should therefore cool off more rapidly than the larger Earth — but more slowly than the smaller moon. It should have remained more active for longer than the moon, but both its activity and the duration of its activity should have been less than that of Earth. This is, in fact, what is observed: After 4.5 billion years of evolution, Mars is running down while Earth remains dynamically developing in ways Mars never did.

It's possible to be more precise in the analysis of how heat is lost over the lifetime of a planet. If the size, composition and original temperature of a planet are known, computer simulations can be made of the way heat is transported through the planet over time. It is possible to calculate the expected temperature at any depth any time after the planet forms (that is, the computer can "evolve" the planet in time). Calculations of this sort have been done by Nafi Toksöz and his colleagues at the Massachusetts Institute of Technology. There is, of course, some uncertainty in these model planets, but one point seems clear: The evolutionary activity of Mars reached a peak more than one billion years ago, and has been declining ever since. The planet is now cooling too rapidly for there to be major developments of the kind required for plate tectonics.

This means that geologic activity on Mars will continue to decrease. In the future there will be less volcanism and rifting than has already occurred. Mars has little — if any — internal convection; it will have even less in the future as it loses its remaining heat. Uplift and rifting of the crust will become impossible. Mars will never have plates, nor plate motion. The planet has already come as close as it can to being Earthlike in its evolutionary development.

Although there will never be folded mountains or immense spreading centers on Mars, we are fortunate that such a planet exists in the solar system. Had Mars been much larger, its activity would have been more like that of Earth, and perhaps dynamic enough to have destroyed the record of how the processes began. This is the problem we have with Earth: Our planet is so active that the earliest rocks have been eradicated. We have no reliable record of what our world was like three and four billion years ago. Likewise, if Mars had been smaller, then its development — like that of the moon or Mercury — would have been brief and aborted with little volcanic or tectonic activity. Because Mars is twice as large as the moon and half the size of Earth, its evoluion has been slow enough and sluggish enough that we see the beginnings of plate tectonics growing out of a world originally dominated by the effects of impact.

It is for this reason that planetary scientists are confident that early Earth could well have been like the moon: heavily cratered regions and large lava plains filling the major impact basins. But because Earth was so hot, it could not have remained this way for long. The need to lose its rapidly growing internal heat led to active convection, in turn producing uplifted and rifted crust. Breaking of this crust into hundreds of small, rapidly moving plates probably followed quickly. The violence of the earliest small-plate tectonics can be estimated from calculations of heat loss over time. So great was Earth's activity during its hotter, earlier history that little remains of the original plates: The rocks have been extensively reworked and recycled in the fast motions of the smaller plates of the early Earth.

The lack of plates on Mars has been useful in the study of Earth's early history, providing clues which would not otherwise be available. Though Mars has ended its active phase of development, and is slowly slipping into inactivity, the features formed during its prolonged evolution remain today as important signposts describing the very fundamental processes of planetary evolution that shaped not only Mars, but Earth as well.

Herbert Frey received his Ph.D from the University of Maryland in 1977; his thesis was on the early crustal evolution of Earth, using information derived from comparative studies of the planets. Frey currently works at Goddard Space Flight Center and teaches at the University of Maryland.

ASTRO-NEWS

Latest News From the World of Astronomy

New Computer Simulates Cosmic Events

Using the world's most powerful computer as a miniature universe, scientists are now "seeing" the birth and evolution of stars and galaxies, including our own.

By compressing 200 million years into several hours computer time — and reducing the distance light travels in 100,000 years to the length of a television screen — they are witnessing galaxies colliding and gas clouds giving birth to embryonic stars.

These simulated cosmic events threaten to alter traditional ideas of how galaxies form, what shapes they assume and what happens when they collide.

Elliptical galaxies were thought to be oblate — flattened spheres shaped like frisbees. But computer generated elliptical galaxies (at NASA's Ames Research Center in Mountain View, Calif.) reveal their three-dimensional shape to be prolate or oblong, like cosmic footballs. And astronomers are now reporting observational evidence confirming the computer's discovery.

It is beginning to appear to Ames researchers doing much of the pioneering work that computer simulation of cosmic events is an important factor in fully understanding the dynamics of the universe. Astronomers now have a "laboratory" to test theories and conduct experiments.

The Ames team (led by University of Chicago astronomer Dr. Richard Miller and Ames astrophysicist Dr. Bruce Smith) is instructing Ames' ILLIAC IV computer — the world's most powerful — to create swirling systems of 100,000 computer points. Each point represents the mass of about one million of our suns to give the simulated galaxy a realistic total mass. Each point "feels" the gravitational tugs of its neighbors and "absorbs" energy from exploding supernovae.

Over the last few years, Miller and Smith have developed a detailed computer program to study the formation and dynamics of galaxies. By coupling this code with the computational power of ILLIAC IV, they have proven computer simulation is a very useful approach to explaining some basic astrophysical processes.

Miller and Smith routinely follow up to 120,000 "stars" which are free to move about in a "cube" — a three-dimensional boundary of space created by the computer, corresponding to 100,000 light-years from edge to edge. They can order ILLIAC IV to rotate the cube so they can watch events from every angle, and can view swirling dust clouds from below or peer down at gigantic galactic collisions.

Scientists at Ames have filmed several computer simulations. These films reveal events which were not expected according to traditional theories of astrophysics. For example, vast congregations of computer generated stars repeatedly evolve into stable prolate bars. These bars rotate end over end like a football, and may be the true shape of elliptical galaxies.

The Ames team suggest that elliptical galaxies seen through the telescope are really the same prolate bars generated by the computer, but seen in various projections. Astronomers view snapshots of galaxies projected onto the sky. They have only one view of the galaxy and can only guess at its shape, since it would take millions of years to track the galaxy across the sky and view it from a different perspective.

But with a powerful computer, they can "examine" such galaxies from every direction and easily visualize its three-dimensional form. Confirmation of the computer's revelations concerning the shape of elliptical galaxies has now been reported, based on observed velocities of the galaxy's stars.

When Miller and Smith set two

Computer *continued on page 64*

Scientists follow two computer simulated galaxies set on a collision course. The width of the television screen represents a distance of 100,000 light-years. Use of the computer as an astronomical "lab" may be a key to fully understanding the dynamics of the universe. The researchers are Dr. Richard Miller (foreground) and Dr. Bruce Smith. NASA photograph.

Are Neutron Stars Shiny?

At the ultradense surfaces of neutron stars, atoms smashed into neutrons may reflect x-rays like a mirror reflects light. X-rays are not usually reflected. They penetrate matter at normal densities — like our bodies — making them useful to us. Because most matter is transparent to x-rays, if you had "x-ray eyes", most normal objects would look glassy or transparent.

Physicists at the Max-Plank Institute in Germany have been trying to understand the pattern of flashes they see from the x-ray star Hercules X-1, a binary neutron star. The x-rays occur in brief repetitive pulses every 1.24 seconds. However, the pulses are different at different x-ray wavelengths. At low energies two peaks are seen, at medium energies only one, and at high energies two again. They propose that astronomers see only the basic "lighthouse" beam of x-rays in the middle energy range, but at the higher and lower energies that they see reflections from a shiny neutron star surface, adding the extra pulse. Not only must the neutron surface be shiny, but it must also be a "colored" mirror because it reflects high and low energy x-rays best at different angles.

The picture is complicated still more because the neutron star is expected to have a "foggy" atmosphere at x-ray wavelengths! As x-rays travel through the fog, their properties are further changed.

The physicists, R. Lenzen and J. Trumper, say it seems likely the neutron star surface will be smooth enough to act like a shiny mirror. If the surface of the neutron star was rough, it might reflect x-rays more like a piece of crumpled aluminum foil does light.

Computer *continued from page 63*

50,000-star galaxies on a collision course, there was much greater interaction between the colliding galaxies than was forecast. The galaxies were first seen to contract, their gravitational fields reinforcing each other. But then, they bounced back in a violent expansion that flung hundreds of stars out of the galaxies. The end result was a merger of the two galaxies, but with considerably fewer stars.

Curiously, spiral shaped galaxies – such as the one to which Earth belongs — never appear for long without assuming the prolate bar shape. This perplexing situation means that our knowledge concerning the physics of spiral galaxies is inadequate. Other basic physical processes must play a role in the formation of stable spiral galaxies.

Ames researchers are presently following simulated masses of gas as they coalesce and form stars. Some stars are programed to have a short life, collapsing into brilliant supernova eruptions, spewing their masses out into the primordial galaxy. In this area, too, Miller and Smith are expecting surprises from ILLIAC IV. Perhaps more theories concerning the nature and evolution of the universe may change as the gigantic computer reconstructs events which took place at the beginning of time.

Fastest Asteroid?

Eleanor Helin and her colleagues are quite ecstatic; they've found another Earth-crossing asteroid! Discovered Sept. 10, 1978 with the 18 inch Hale Observatories Schmidt, the new object (so new it has no name) was 10-1/2 magnitude and moving two degrees per day when found. Its orbit links it with 1976 AA and 1976 UA, the three comprising a group called the Aten family. With a semimajor axis of only 0.83 astronomical units, the new object has the smallest known asteroidal orbit, revolving about the sun in nine months or less. Researchers at the University of Arizona and Mauna Kea Observatory have obtained preliminary data showing that the new object has a rotational period of 12 hours, and may be a type "C" carbonaceous chrondrite.

NASA Best Seller

More than 233 "customers" seeking small, inexpensive tickets aboard the Space Shuttle have purchased NASA's "Getaway Specials".

Getaway Specials cost from $3,000 to $10,000, depending on size (three to five cubic feet) and weight (200 pounds maximum). They will be flown on a space-available basis aboard the Shuttle starting in 1980.

The West German Federal Research Ministry has purchased 25 for materials processing experiments, and seven have been purchased by various domestic and foreign publications.

Many have been purchased by businesses (such as Edmund Scientific Co.), civic clubs, museums or other organizations seeking to give college and high school students an opportunity to fly experiments in space.

New Zero Gravity Simulation Tank

A water immersion facility will be built at Johnson Space Center in Houston, Tex., so Space Shuttle astronauts can train underwater for space walks.

The facility will be built despite efforts by Alabama congressmen to block it.

A million gallon neutral buoyancy simulator at Marshall Space Flight Center in Huntsville, Ala., has been in use since the 1960s. In it, suited astronauts and engineers can simulate the mechanics (but not all the physiology) of working weightless.

The Marshall tank was used extensively in 1973 to work out repair procedures for the crippled Skylab space station. The tank simulations were so effective that one Skylab astronaut, during a space walk, looked down at Earth and said: "Just like the tank at Huntsville — only deeper."

The Marshall tank is 40 feet (12 meters) deep, 75 feet (22-1/2 meters) across and holds one million gallons of water. It is now in use for work on large space structure assembly.

NASA had attempted for at least four years to get funding for a similar facility at Johnson. But Representatives Ronnie Flippo and Walter Flowers, Alabama democrats, had succeeded each year in blocking funds on the grounds that it would be a duplication of facilities and a waste of money.

This year, though, NASA found itself with residual construction-of-facility funds at several centers, including Johnson. NASA notified the House Space Appropriations Committee that it intended to reprogram that money, including $860,000 for construction of the Johnson tank. The reprogramming could be stopped only by objection of a majority of the committee which is chaired by Representative Olin Teague, a Texas democrat.

The Johnson tank will be 78 feet (23-1/2 meters) long, 30 feet (10 meters) wide, and 25 feet (7-1/2 meters) deep, with about 1/3 the volume of the Marshall tank. One end will be a semicircle. The tank will be large enough to hold a full mockup of the Shuttle cargo bay and cockpit with room for work around it. It does not appear to be large enough for space structure work, though. Completion is expected in June 1979.

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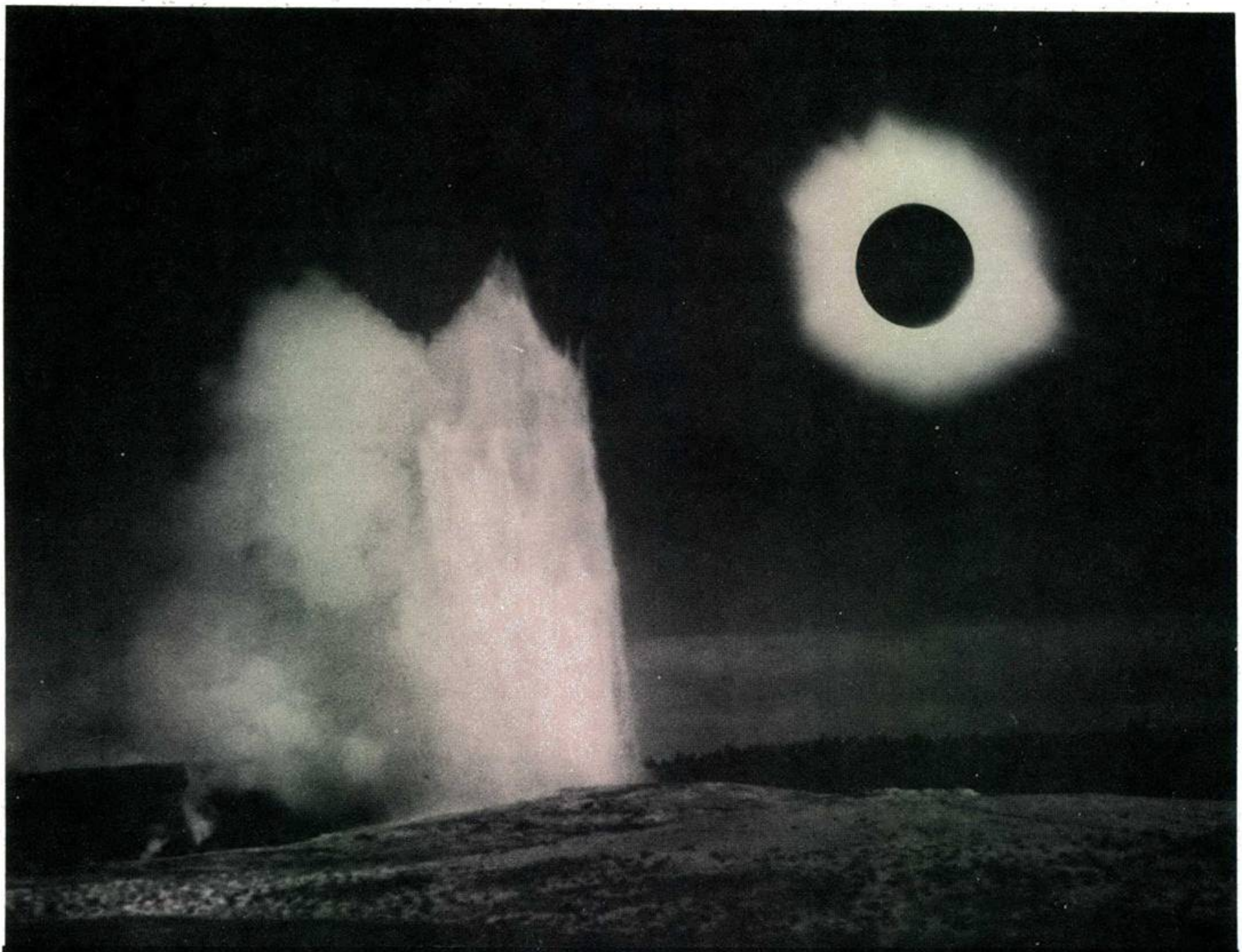

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The price—$385.00 per person—includes four nights lodging, all meals, tours, bus transportation to and from the airport, bus transportation to the eclipse site, and devices to view the partial phases. A major highlight of the package, also included in the price, is a specially designed science/eclipse lecture series featuring prominent authorities in meteorology, astronomy, eclipse photography, astrophotography, modern exploration and the philosophy of science.

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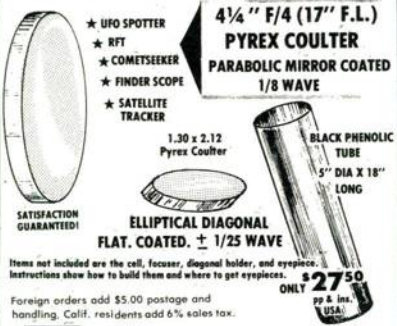

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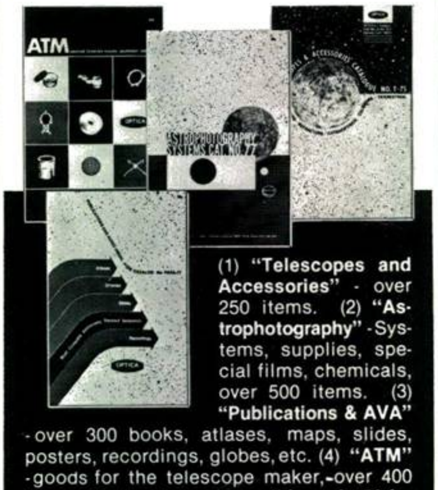

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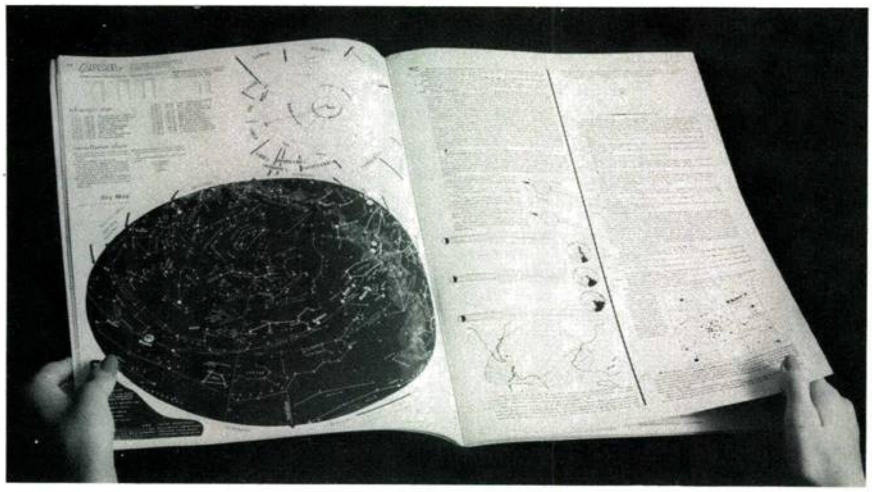

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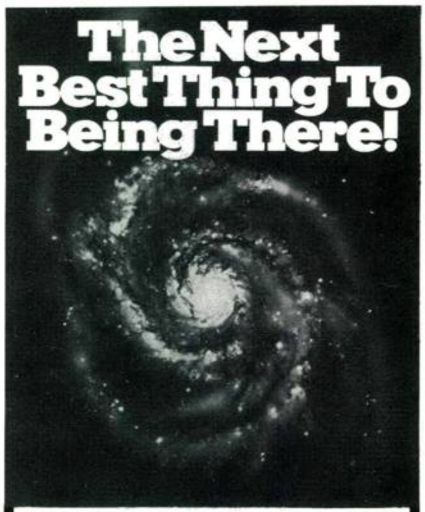

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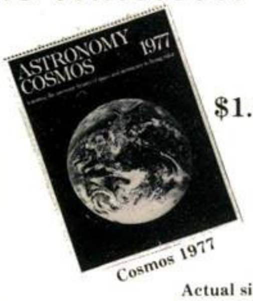

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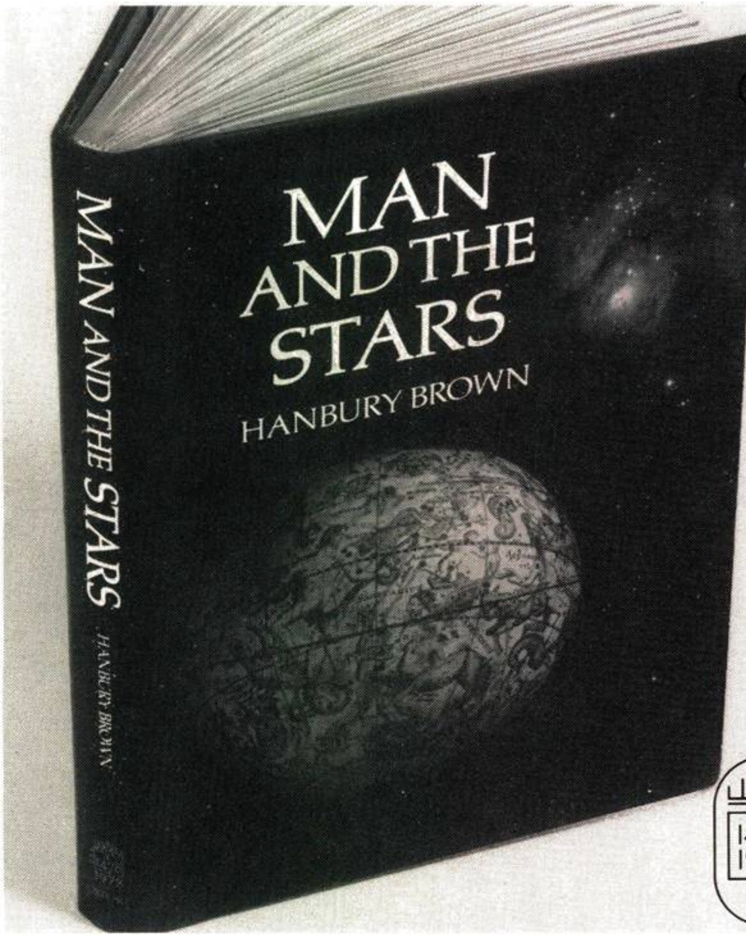

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STAR DOME

NOVEMBER

by
James Mullaney

With the arrival of November, we know that winter is on its way. The glorious golden days of autumn have faded to a crisp dry brown beneath our feet, and while longer nights grant us more time for stargazing, an ever colder nip in the air chases us all the sooner back to the warmth of home and hearth. For those who persevere, however, the November sky has tales to tell — ancient campfire tales of adventure and horror — and wonders to display.

November evenings bring the vast array of six great constellations, tied together in a single tale, into full view: Cepheus, Cassiopeia, Perseus, Andromeda, Pegasus and Cetus. The full story (recounted in detail in Star Dome, November 1976) is a fitting one for late fall, full of strangeness and mystery, and complete with weird monsters, a beautiful maiden to be rescued, a bold adventurer, and lots of magic!

Of course, two of these "epic" constellations are always on view: Cepheus and Cassiopeia, both circumpolar constellations which never drop below the horizon. Perhaps this is fitting for these two, as they are the "royal" constellations — the king and queen of the epic tale. They preside in the north, swinging round and round the pole, ever reigning over their domain as Perseus, Andromeda and the others sink out of sight. But the honor attached to such an eternal rule may be questioned, for indeed, it is said that such a fate is a punishment for Queen Cassiopeia's pride — to be swung upside-down on her throne every night!

The giddy queen, much more prominent than her kingly consort Cepheus, is one of the most easily recognized constellations. The five brightest stars form a distinctive figure — either in the form of the letter M or W, depending on whether it is respectively above or below the pole — lying in a very rich section of the Milky Way.

But Cassiopeia is more famous because of an even brighter star — one of the grandest sights ever to have appeared in the heavens — but which is now nowhere to be found! This was the great supernova of 1572 A.D., better known as Tycho's star, even though he was not its "discoverer".

One of only three supernovae definitely known to have flared out in our galaxy in modern times (Kepler's star in Ophiuchus in 1604, and the Chinese "Guest Star" in Taurus in 1054 that produced the Crab nebula were the other two), it was detected on Nov. 11, 1572 by the famed Danish astronomer Tycho Brahe. Although seen by others before him, he was the first to measure its position and changes in brightness.

At maximum light, the new star was brighter than Jupiter (then at opposition and near perihelion), and soon rivaled Venus in radiance, becoming visible in broad daylight! Its apparent magnitude at that time is generally given as -4.0, but some authorities rate it at least 1/2 magnitude brighter, making it more luminous than all other celestial bodies except the sun and moon! At the end of that November it began to slowly fade, and by March 1574 had disappeared from view. It is now thought to be fainter than magnitude 19.

Tycho's star appeared near right ascension 00 hours 22 minutes, declination +63 degrees 52 minutes (1950 coordinates), about 1-1/2 degrees northwest of Kappa Cassiopeiae. The next clear moonless night, why not cast a respectful glance at the place of its remains and in your mind relive that glorious event of so long ago? Tycho himself called it "a miracle indeed" — and perhaps, after all, that's just what it was.

Close-Up

Cassiopeia Region

Few parts of the sky offer fields richer than Cassiopeia for nightly prospecting by astronomy enthusiasts. As Olcott expressed it: "A mine of interest is here revealed for the happy possessor of a telescope."

Barns considered this group: "... one of the most beautiful and familiar configurations of the northern heavens, being 'always with us as a low lying W or a vaulting M, dervishing daily about the pole star directly opposite the Big Dipper.... Many striking diversities abound here — binaries, clusters, nebulae and vari-tinted units — with a grand stellar highway from Gamma southwest to Alpha Cas, well worth traversing leisurely... comprising some of the noblest objects to lure the explorer...."

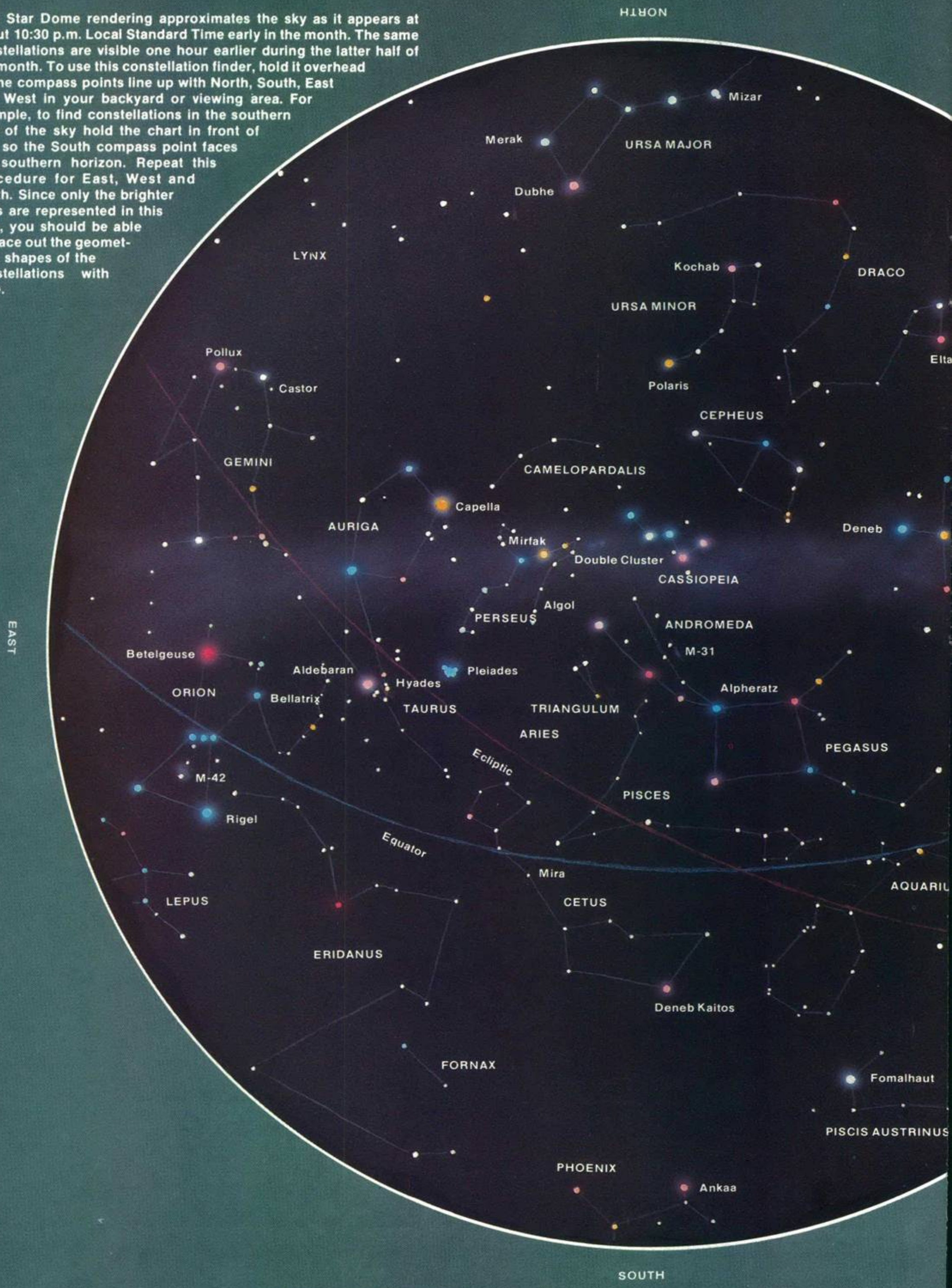
Many of Cassiopeia's brighter units are known or suspected variable stars of one type or another. The leader Alpha, or Schedar, was once considered an irregular variable ranging between second and third magnitudes in an indefinite period. Webb noted it as "slightly variable" and suspected a period of 79 days. Yet, in recent times, its light has been relatively constant, and there is now doubt that it is really variable at all! However, other known irregulars like Betelgeuse in Orion have remained constant for long periods. There is even the case of RU Camelopardalis (a well-known Cepeid) that was found in 1966 to have actually stopped its pulsations! Alpha could simply be in a resting period at present and deserves a watchful eye from observers. It shines at magnitude 2.2 and should be compared with nearby Beta (itself slightly variable by a few hundredths magnitude) at 2.3. Among the other bright stars in Cassiopeia that are or may be variable are Gamma, Delta, Iota and Rho, making an impressive chest of glittering jewels for the queen!

Eta (η) Cassiopeiae

Foremost of this region's multitude of double and multiple stars is Eta Cassiopeiae — a contrasty pair offering one of the most pleasing effects of color in the entire heavens. Readily visible to the unaided eye, look for it 1/3 the distance from Alpha (α) to Gamma (γ).

Eta Cassiopeiae is a well observed visual binary having an orbital period of around 480 years. Discovered by William Herschel in 1779, it has been closely followed since about 1830. The two stars were closest in their apparent orbit in 1890 (five seconds of arc), and will be widest around the year 2125 (nearly 15 seconds). At

This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease.


NORTH
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DRACO
URSA MINOR
Pollux
Castor
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CEPHEUS
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CAMELOPARDALIS
Capella
AURIGA
Deneb
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Algol
PERSEUS
ANDROMEDA
EAST
M-31
Betelgeuse
Aldebaran
Pleiades
Hyades
ORION
Bellatrix
Alpheratz
TAURUS
TRIANGULUM
ARIES
PEGASUS
Ecliptic
M-42
PISCES
Rigel
Equator
Mira
AQUARIU
LEPUS
CETUS
ERIDANUS
Deneb Kaitos
FORNAX
Fomalhaut
PISCIS AUSTRINUS
PHOENIX
Ankaa
SOUTH

Map Centered on 40° North Latitude

HERCULES
Vega
LYRA
CYGNUS
WEST
DELPHINUS
Altair
AQUILA
EQUULEUS
CAPRICORNUS

Map by Adolf Schaller

present, both the separation and position angle are slowly increasing. This stunning duo lies just over 18 light-years from us, considerably closer than most of the prominent double and multiple stars visible in smaller instruments.

Robert Burnham Jr. pointed out that Eta "has an especially beautiful contrast in colors". While most observers find these tints to be yellow and purple, other impressions are to be had, as the following roundup from the logs of the classic observers indicates: yellow and Indian red, yellow and blue, red and green, pale white and purple, topaz and garnet, gold yellow and purple, yellow and pale garnet, and orange and gold. How do you find this pair in your telescope?

The primary of this duo is of spectral type G, while the secondary has been classified as both K and M — in either case agreeing well with the colors reported visually at the telescope. The pair has been called the Easter Egg double from its lovely tints appropriate to that occasion, and one modern observer has likened it to a hot air balloon with a lighted gondola drifting through the sky, as seen through his six inch reflector at low power! (The companion is in such a position — due west of the primary — that it would give the effect of "descending" in an undriven instrument due to Earth's rotation.) As these analogies suggest, Eta is sure to grab your attention and quickly become one of your favorite objects.

Sigma (σ) Cassiopeiae

Another of this region's colorful doubles is Sigma Cassiopeiae, the southerly member of the Rho (ρ)-Sigma naked eye pair southwest of Beta (β). The tints here lie at the other end of the visible spectrum from those of Eta — a unique green and blue combination! Our drawing with a six inch reflector at 150 power shows the pair at the same scale as Eta, and hints at the exquisite heavenly hues present.

The components here are of fifth and seventh magnitudes, and are separated by just three seconds of arc near position angle 330 degrees (northwest-southeast on the sky). At low power on a three or four inch scope, Sigma is not resolved but has another star fainter than itself in the field some distance to the west. With 100 power in good seeing, the pair is neatly separated with these apertures and some hint of the unusual colors can be had. But at least a six inch is needed for a really good view. So equipped, most observers find the primary a delicate greenish-white in cast and the companion an intense clear blue.

Smyth recorded the stars as "flushed white and smalt blue", and Webb, green and very blue, and again white and tawny, adding "glorious low powered field." Olcott also gave green and blue, remarking "colors intense, grand field with low power". Barns simply stated that the field was "teeming with jewels", without any mention of colors present.

Both components of Sigma Cassiopeiae are hot, early B type suns, apparently in very slow orbital motion about each other, at least 800 light-years apart. A green-blue combo like this one is rather rare among bright doubles, so why not check it out the next clear tranquil night? To help you appreciate its uncommon beauty, alternate views with nearby Eta — an exercise guaranteed to delight the visual senses!

Struve 163

We seldom have space in Close-Up to highlight the many faint but beautiful double and multiple stars to be found in the Struve catalogs. Generally bypassed by observers in preference to those objects having Greek letters or Flamsteed numbers, they are nonetheless often superb sights in even the smallest telescopes, and are well worth the time to locate them. An example can be found in the pair Struve 163, visible in a finder one degree northwest of Epsilon (ϵ) Cassiopeiae. Although not plotted on most atlases (including Becvar's), it does appear in Norton's, which shows hundreds of Struve objects.

Struve 163 consists of sixth and eighth magnitude stars a wide 35 seconds apart near position angle 35 degrees. They are well seen in a two inch refractor at 30 power, but — as is the case for fainter pairs in general — a somewhat larger aperture is needed to collect the light necessary for good color perception. A four inch scope at 45 power does well on this object, but a six inch is even better. Whatever instrument is employed, the lowest power available should be used so that the stars are not unduly separated, thereby reducing the contrast effect present here.

Smyth logged Struve 163 as "red gold, blue; remarkable colors", and Webb stated "colors splendid". Franks found the tints "ruddy orange and blue"; Norton, "splendid gold and blue", and Muirden "rich gold and blue; fine contrast". Barns again noted "colors contrasty" without specifying those seen. As these commentaries suggest, this object is something of a minor showpiece — yet few modern observers have ever seen it!

There are many hundreds of stunning pairs like Struve 163 hiding in undeserved obscurity, some of which haven't been looked at in more than a century. While many observers actively work their way through the Messier and Herschel lists, there appears to be no one surveying the

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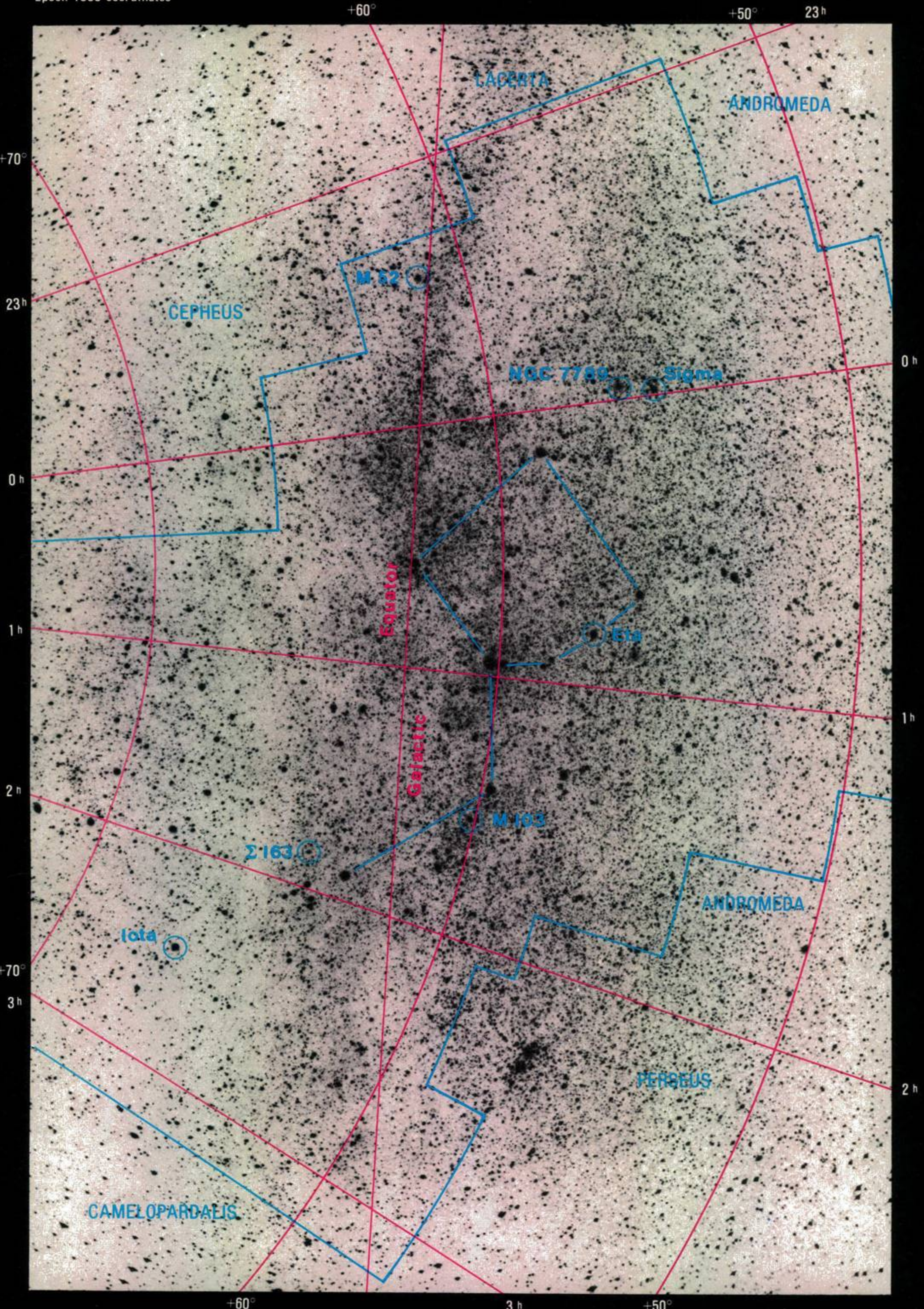

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0 h
NGC 7789
Sigma
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Equator
Eta
1 h
1 h
Galactic
2 h
M 103
Σ 163
ANDROMEDA
Iota
+70°
3 h
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2 h
CAMELOPARDALIS
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3 h
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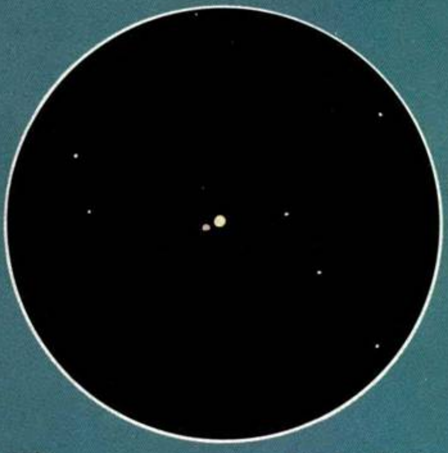
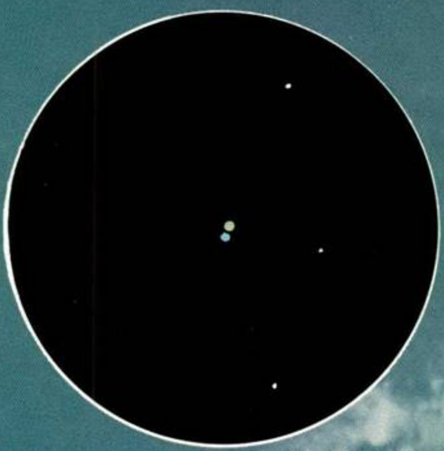
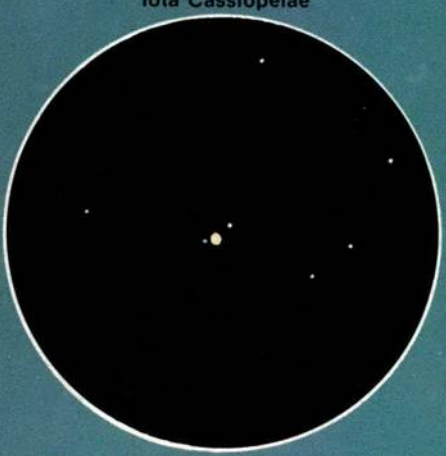
Eta Cassiopeiae



Sigma Cassiopeiae



Iota Cassiopeiae



These three views of multiple stars in Cassiopeia are drawn to the same scale, as seen with a six inch reflector at 150 power. Top left: Eta Cassiopeiae — also known as the Easter Egg double because of its lovely tints — presents one of the most pleasing color contrasts in the sky. Top right: The rare blue/green combination of Sigma Cassiopeiae requires at least six inches aperture for a good view. Bottom: Having a bright primary together with two dimmer companions, the striking triple system of Iota Cassiopeiae is in reality quadruple. Drawings by James Mullaney.

double star lists of the Struves. Such a project would be ideal on those hazy or moonlit nights when clusters and nebulae are washed out, especially for those possessing medium to large sized scopes. Perhaps a glimpse of Struve 163 will motivate you to such a worthy and enjoyable undertaking.

Selected Objects — Cassiopeia Region

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.
NGC-133	OC	9.4	7′	00^h28^m	+63°04′
λ (Lambda)	★2	5.5,5.8	0.6″	00^h29^m	+54°15′
NGC-146	OC	9.8	6′	00^h30^m	+63°01′
α (Alpha)	★2	2.2,9.0	62″	00^h38^m	+56°16′
NGC-225	OC	9.1	12′	00^h40^m	+61°31′
*η (Eta)	★2	3.6,7.5	12″	00^h46^m	+57°33′
γ (Gamma)	EV	1.6-3.0	—	00^h54^m	+60°27′
NGC-457	OC	7.5	10′	01^h16^m	+58°04′
PS1	★3	5.0,8.9,9.5	25″,3″	01^h22^m	+67°52′
*M-103	OC	7.4	5′	01^h30^m	+60°27′
NGC-663	OC	7.1	11′	01^h43^m	+61°01′
*Struve 163	★2	6.2,8.2	35″	01^h48^m	+64°36′
*ι (Iota)	★3	4.7,7.0,8.3	2″,7″	02^h25^m	+67°11′
*M-52	OC	7.3	12′	23^h22^m	+61°20′
ρ (Rho)	IV	4.1-6.2	—	23^h52^m	+57°13′
*NGC-7789	OC	9.6	30′	23^h55^m	+56°26′
*σ (Sigma)	★2	5.1,7.2	3″	23^h56^m	+55°29′
R	RLPV	5.3-12	432^d	23^h56^m	+51°07′
WZ	RSV	6.9-8.5,8	186^d/58″	23^h59^m	+60°05′

*Detailed in Close-Up

OC = **Open Cluster**
★2 = **Double Star**
EV = **Erratic Variable**
★3 = **Triple Star**
IV = **Irregular Variable**
RLPV = **Red Long Period Variable**
RSV = **Red Semiregular Variable/Double Star**

Iota (ι) Cassiopeiae

We move on now to sample one of the many multiple stars in this month's region. This is the striking triple system Iota Cassiopeiae, easily found by following a line from Delta (δ) through Epsilon, extended the same length again. For a good view of this object, medium powers and apertures will be needed, as well as a night having good seeing (image steadiness).

Iota is made up of a 4.7 magnitude yellowish primary, and 7.0 magnitude blue and 8.3 magnitude blue-white companions. The small stars lie at distances of just over two and seven seconds in position angles 240 and 114 degrees, respectively. Our sketch with a six inch reflector at 150 power again shows this object at the same scale as Eta and Sigma, allowing a direct comparison of what should be seen.

Although generally considered a fine object for a four inch telescope, most observers will find it rather disappointing in anything less than a six inch on an average night. Webb found this trip "fine but not easy" in his 3.7 inch refractor in 1850. (The widely used Dover reprint edition of his work omits the word "not", completely changing the meaning of the original description.) His impression of the colors, in order of brightness, was yellow, lilac and blue — very similar to Smyth's yellowish white, purplish and fine blue.

Although Olcott stated that a three inch scope showed only two stars in Iota, Burnham countered with this in his description: "One of the finest triple stars in the sky, resolvable in a good three inch telescope when seeing conditions permit." Muirden called this object "a splendid triple star", and Barns "not difficult; very fine" in his 10 inch reflector. Brown noted it as "colorful" and felt that the close pair needed at least 140 power for a clean split. Iota did not quite make Pickering's roster of the sky's finest showpieces, being a "runner up" to the primary list. He explained: "The close pair are very unequal and not well adapted to small telescopes." Do you agree with his assessment of this object?

While changes in separation and position angle of the components have been very slow, Belgium astronomer Jean Meeus found that the three stars were exactly on a straight line (companions on opposite sides of the primary) about the year 1807. The closer member has moved noticeably off this line in the intervening years due to orbital motion, whose period Charles Worley gives as 850 years. The primary also has an unresolved star circling it in a period of 50 years, so Iota is in reality at least a quadruple system.

M-103

We come at last to the real glory that is Cassiopeia — its many glittering open star clusters! Of this horde, three stand out as worthy of special recognition by backyard astronomers. One of these is M-103, situated just one degree northeast of Delta Cassiopeiae in the direction of Epsilon. Although it and the following two clusters can be seen in binoculars, they are best picked up by sweeping with a low power wide field eyepiece on the telescope itself — preferably on a dark (moonless) transparent night for optimum effect.

Last of the entries in the original Messier catalog, M-103 shines near seventh magnitude and is some five minutes in size. Despite its 60 or so member stars, it is considered loose and poor as open clusters go. Yet it has a special appeal all its own, bringing observers back time and again for another look.

A four inch scope at 45 to 90 power reveals M-103 as a triangular shaped splash of suns with a brighter star at each of its corners. The brightest of these is an attractive double — Struve 131 (magnitudes six and nine, separation 14 seconds), described by Smyth as "straw and dusky blue" in tint. There is also a wide pair at its center.

Webb considered this cluster a "beautiful field", and Barns saw it as a "vivid cluster in grand setting". Norton felt that M-103 was "rather loose but lies in a beautiful field", while Brown logged it as "fan shaped" in form.

Messier authority Holyoke's description runs in part: "The whole area is beautiful but the cluster is hard to make out as it gets lost in its surroundings...." In contrast, Burnham stated, "This is not one of the richer clusters but is a fairly compact group, with a much-flattened or wedge shaped outline, and easily identified when sweeping the area with a low power." How do you find this starry triangle — easy or difficult to identify?

Recent determinations of M-103's distance from us place it at nearly 8,000 light-years — twice that of earlier estimates.

NGC-7789

Our second Cassiopeian jewel box is an amazing cloud of distant stardust neatly tucked within the two degree gap between the stars Sigma and Rho Cassiopeiae. This is NGC-7789, discovered by Carolyn Herschel (Sir William's sister) and labeled HV-I — 30 in his great catalog.

Softly glowing at magnitude 9.6 and nearly 30 minutes in size, NGC-7789 contains at least 200 members and is considered intermediate rich in concentration. Burnham gave the cluster's population as closer to 1,000 suns, agreeing better with the visual impression in large instruments. Indeed, so rich and uniform is this swarm that some observers consider it a semiglobular cluster — an object intermediate in type between the loose opens and densely packed globulars. (We've encountered other such objects in past installments of Close-Up, notably M-11 in Scutum, M-71 in Sagitta and NGC-2158 in Gemini.)

Burnham provided an excellent description of what is to be seen here by the stargazer: "To the observer with binoculars, it is a hazy patch of unresolvable stardust; in a good three inch glass a rich sprinkling of star points begins to appear across its surface, and the view grows steadily more impressive with every increase in the size and quality of the telescope."

So softly does this host of suns glow that it can be passed over completely while sweeping, especially in small instruments. Once recognized, an immediate thrill is experienced along with amazement that so beautiful a sight could escape attention. NCG-7789's aspect in a six or eight inch reflector at 40 to 60 power is simply fantastic and must be seen to be believed!

Smyth described this object as: "A most superb cluster...on a ground of stardust...a glorious assemblage...with spangy rays of stars...a mere condensed patch in a vast region of inexpressible splendor, spreading over many fields...." Webb found it a "beautiful large faint cloud of minute stars" and Chambers, "a superb cluster of small stars". John Herschel recorded it in his log as "a most superb cluster which fills the field and is full of stars, gradually brighter in the middle but without nuclear condensation". And last but not least, Barns tersely noted it as "radiant".

As these excited commentaries clearly indicate, NGC-7789 is a real showpiece within its class and is not to be missed while exploring this region. Despite its distance of some 6,000 light-years from us, this stellar commune has the amazing ability to fire the spirit of receptive observers upon first sight!

M-52

Our final selection from this month's region is another open cluster from the Messier catalog — this one, M-52. A line extended from Alpha through Beta slightly more than its length points to its place in the sky, just one degree south of the fifth magnitude star 4 Cassiopeiae. Lying very near the Cassiopeia-Cepheus border, this object appears under the latter constellation in many older lists and books such as Webb's.

M-52 has an integrated (or combined) light equal to that of a seventh magnitude star, and measures at least 12 minutes of arc in size (some sources make it nearly twice this apparent extent). Classified as intermediate rich in concentration, its stellar population numbers at least 120 suns. In a three or four inch telescope at 45 power, the cluster appears as a rich, compact, uniformly bright splash of stars shaped something like a half moon. As seen in 8 to 12 inch reflectors at low power, it is a magnificent sight — one never to be forgotten!

Brown found M-52: "A bird-in-flight group of about 120 small stars with a magnitude eight orange star at the head. Somewhat like popular M-11 but less bright." He went on to tell us that Messier saw it in his imperfect instruments as "a mass of very small stars blended with nebulous matter and requiring a good telescope to distinguish them". Barns, with a vastly better scope, called it an "extended cluster, fairly clear".

Webb described M-52 briefly as "irregular, with an orange star as is frequently the case"; Muirden said, "A most beautiful cluster, somewhat triangular. A three inch shows it granular with faint stars." Smyth's account is similar to both of these: "Irregular and of a somewhat triangular form with an orange tinted eighth magnitude star at the vertex, giving the resemblance of a bird with outstretched wings."

Interestingly, John Herschel called M-52 round rather than irregular in his description, and Holyoke reported he had difficulty seeing the bright orange star mentioned by Webb and other observers. Yet, this object is obvious in even the smallest of instruments, looking more yellow than orange to some observers.

The presence of a bright star near the apparent center of many open clusters has frequently been mentioned in accounts like those above by visual observers, but has received little attention from professional astronomers. Perhaps this is not so surprising, for such an object may be very striking to the eye as in the case of M-52, yet attract little attention on modern time exposure photographs or photoelectric photometer printouts!

This circumstance leaves the attentive visual observer wondering about a possible connection between such stars and their host clusters. Is it merely a matter of cosmic coincidence — the chance alignment of field stars against the clusters — or is there some actual physical connection between the two? Such speculation at the eyepiece is entirely proper and worthy of the observer as he seeks an ever deeper understanding of the wonders he beholds.

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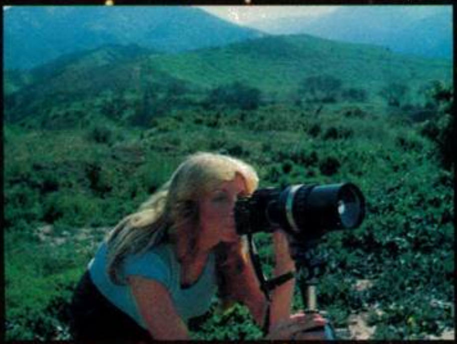

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